

NISTIR 4814



A11103 740188

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NIST Express  
Working Form  
Programmer's  
Reference

Revised April, 1992

Stephen Nowland Clark  
Don Libes

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4814  
1992

992

NIST



## National PDES Testbed Report Series

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April 3, 1992

# NIST Express Working Form Programmer's Reference

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Stephen Nowland Clark  
Don Libes





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# NIST Express Working Form Programmer's Reference

Stephen Nowland Clark

Don Libes<sup>1</sup>

## 1 Introduction

The NIST Express Working Form [Clark90b], with its associated Express parser, Fed-X, is a Public Domain set of software tools for manipulating information models written in the Express language [Part11]. The Express Working Form (WF) is part of the NIST PDES Toolkit [Clark90a]. This reference manual discusses the internals of the Working Form, including the Fed-X parser. The information presented will be of use to programmers who wish to write applications based on the Working Form, including output modules for Fed-X, as well as those who will maintain or modify the Working form or Fed-X. The reader is assumed to be familiar with the design of the Working Form, as presented in [Clark90b].

### 1.1 Context

The PDES (Product Data Exchange using STEP) activity is the United States' effort in support of the Standard for the Exchange of Product Model Data (STEP), an emerging international standard for the interchange of product data between various vendors' CAD/CAM systems and other manufacturing-related software [Mason91]. A National PDES Testbed has been established at the National Institute of Standards and Technology to provide testing and validation facilities for the emerging standard. The Testbed is funded by the Computer-aided Acquisition and Logistic Support (CALS) program of the Office of the Secretary of Defense. As part of the testing effort, NIST is charged with providing a software toolkit for manipulating STEP data. This NIST PDES Toolkit is an evolving, research-oriented set of software tools. This document is one of a set of reports which describe various aspects of the Toolkit. An overview of the Toolkit is provided in [Clark90a], along with references to the other documents in the set.

---

1. Don Libes is responsible for the minor changes made to this document to track the actual implementation of the software described. However, credit for the bulk of the document, its style, and the implementation of the NIST Express Working Form remains with Stephen Nowland Clark. Recent changes are denoted by a change bar to the left of the text.

## Fed-X Control Flow

A Fed-X translator consists of three separate passes: parsing, reference resolution, and output generation. The first two passes can be thought of as a single unit which produces an instantiated Working Form (WF). This Working Form can be traversed by an output module in the third pass. It is anticipated that users will need output formats other than those provided with the NIST Toolkit. The process of writing a report generator for a new output format is discussed in detail in section 4.

### 2.1

#### First Pass: Parsing

The first pass of Fed-X is a fairly straightforward parser, written using the Unix™ parser generation languages, Yacc and Lex. As each construct is parsed, it is added to the Working Form. No attempt is made to resolve symbol references: they are represented by instances of the type `Symbol` (see below), which are replaced in the second pass with the referenced objects.

The grammar used by Fed-X is processed by Yacc or Bison (a Yacc clone available from the Free Software Foundation<sup>1</sup>). The lexical analyzer is processed by Lex or Flex<sup>2</sup>, a fast, public domain implementation of Lex. Generally, Flex and Bison are faster and provide more features. For portability, some of these features are avoided by Fed-X even though such use might make the result simpler and faster (such as the multiple start condition machinery offered by Flex). When easily handled (such as by conditional compilation (`#ifdef ... #endif` pairs)), certain features of Flex and Bison are taken advantage of. In general, Flex and Bison are preferred over Lex and Yacc. The choice is controlled by the Makefile (and `make_rules`) that directs the building of the system.

### 2.2

#### Second Pass: Reference Resolution

The reference resolution pass of Fed-X walks through the Working Form built by the parser and attempts to replace each `Symbol` with the object to which it refers. The name of each symbol is looked up in the scope which is in effect at the point of reference. If a definition for the name is found which makes sense in the current context, the definition replaces the symbol reference. Otherwise, Fed-X prints an error message and proceeds.

In some cases, the changes which must be made when a symbol is resolved are slightly more drastic. For example, the syntax of Express does not distinguish between an identifier and an invocation of a function of no arguments. When a token could be inter-

1. The Free Software Foundation (FSF) of Cambridge, Massachusetts is responsible for the GNU Project, whose ultimate goal is to provide a free implementation of the UNIX operating system and environment. These tools are not in the public domain: FSF retains ownership and copyright privileges, but grants free distribution rights under certain terms. At this writing, further information is available via electronic mail on the Internet from [gnu@prep.ai.mit.edu](mailto:gnu@prep.ai.mit.edu).

2. Vern Paxson's Flex is usually distributed with GNU software, although, being in the public domain, it does not come under the FSF licensing restrictions.

interpreted as either, the parser always assumes that it is a simple identifier. When the second pass determines that one of these objects actually refers to a function, the Identifier expression is replaced by an appropriate Function\_Call expression.

Thus, the result of the second pass (in the absence of any errors) is a tightly linked set of structures in which, for example, Function\_Call expressions reference the called Algorithms directly. At this point, it is possible to traverse the data structures without resorting to any further symbol table lookups. The scopes in the Working Form are only needed to resolve external references - e.g., from a STEP physical file.

## 2.3

### Third Pass: Output Generation

The report or output generation pass manages the production of the various output files. Control is essentially handed over to the application-programmer-supplied output module loaded at build time.

In theory, the module could do anything, but more typically, the output module translates the Working Form into some other form such as a human-readable report, or input to an SQL database.

A report generator is an object module, most likely written in C, which has been compiled as a component module for a larger program (i.e., with the `-c` option to a UNIX C compiler). The code of this module consists of calls to Express Working Form access functions and to standard output routines. A detailed description of the creation of a new output module appears in section 4.

## 3

### Working Form Implementation

The Express Working Form data abstractions are implemented in Standard C [ANSI89]. Standard C is not essential to Fed-X, and some effort has been taken to make the source Classic C compatible but this work is not complete. Application modules (i.e., output modules) can be written in either Standard C or Classic C.

Each abstraction is implemented as one or more classes, using the Class/Object modules in libmisc [Clark90c]. The data specific to a particular class is encapsulated in a private C struct. This structure is never manipulated directly outside of the abstraction's module. For example:

```
/* the actual contents of a Foo */
struct Foo {
    int i;
    double d;
};

typedef Object Foo;

/* Class_Foo is created in FOOinitialize() */
```

```
Class Class_Foo;
```

Outside of Foo's module, we will never see a struct Foo. We will only see a Foo, which is actually an Object which ultimately points at a struct Foo.

### 3.1 Primitive Types

The Express Working Form makes use of several modules from the Toolkit general libraries, including the Class, Object, Error, Linked\_List, and Dictionary modules. These are described in [Clark90c]. The underlying representation for all of the Working Form abstractions makes use of the Class and Object modules.

### 3.2 Symbol and Construct

All Working Form objects are subclassed from the types Symbol and Construct. After the working form has been built, these types become, in Object-Oriented terminology, abstract supertypes<sup>1</sup> for the various types in the Working Form. The two are quite similar, both in concept and in implementation. Both have an attribute containing the line number on which the represented construct appears in the source file (probably useful only within Fed-X). A Symbol also includes a name and a flag indicating whether the symbol has been resolved.

Abstractions which represent nameable objects are subclassed from Symbol. These include Constant, Type, Variable, Algorithm, Entity, and Schema. The latter three are actually subclasses of another Symbol subclass, Scope. Other abstractions (Case\_Item, Expression, Loop\_Control, and Statement) are subclassed from Construct.

### 3.3 Express Working Form Manager Module

In addition to the abstractions discussed in [Clark90b], libexpress.a contains one more module, the package manager. Defined in express.c and express.h, this module includes calls to initialize the entire Express Working Form package, and to run each of the passes of a Fed-X translator.

### 3.4 Code Organization and Conventions

Each abstraction is implemented as a separate module. Modules share only their interface specifications with other modules. There is one exception to this rule: In order to avoid logistical problems compiling circular type definitions across modules, an Express Working Form module includes any other Working Form modules it uses *after* defining its own private struct. Thus, the types defined by these other modules are not yet known at the time an abstraction's private struct is defined, and references to these other Working Form types must assume knowledge of their implementations. This is, in fact, not a serious limitation: Each Working Form types is implemented as an Object, which is defined when the struct is compiled.

---

1. During the generation of the Working Form, many Symbols are not abstract supertypes.

A module Foo is composed of two C source files, `foo.c` and `foo.h`. The former contains the body of the module, including all non-inlined functions. The latter contains function prototypes for the module, as well as all type and macro definitions. In addition, global variables are defined here, using a mechanism which allows the same declarations to be used both for `extern` declarations in other modules and the actual storage definition in the declaring module. These globals can also be given constant initializers. Finally, `foo.h` contains inline function definitions. In a compiler which supports inline functions, these are declared `static inline` in every module which `#includes foo.h`, including `foo.c` itself. In other compilers, they are undefined except when included in `foo.c`, when they are compiled as ordinary functions.

The type defined by module Foo is named `Foo`, and its private structure is `struct Foo`. Access functions are named as `FOOfunction()`; this function prefix is abbreviated for longer abstraction names, so that access functions for type `Foolhardy_Bartender` might be of the form `FOO_BARfunction()`. Some functions may be implemented as macros; these macros are not distinguished typographically from other functions, and are guaranteed not to have unpleasant side effects like evaluating arguments more than once. These macros are thus virtually indistinguishable from functions. Functions which are intended for internal use only are named `FOO_function()`, and are usually `static` as well, unless this is not possible. Global variables are often named `FOO_variable`; most enumeration identifiers and constants are named `FOO_CONSTANT` (although these latter two rules are by no means universal). For example, every abstraction defines a constant `FOO_NULL`, which represents an empty or missing value of the type.

If an instance of `Foo` might contain unresolved Symbols, then there is a function `FOOresolve(...)`, called during Fed-X's second pass, which attempts to resolve all such references and reports any errors found. This call may or may not require a Scope as a parameter, depending on the abstraction. For example, an Algorithm defines its own local Scope, from which the next outer Scope (in which the Algorithm is defined) can be determined; `ALGresolve()` thus requires no Scope parameter. A Type, on the other hand, has no way of getting at its Scope, so `TYPEresolve()` requires a second parameter indicating the Scope in which the Type is to be resolved.

### 3.5

## Memory Management and Garbage Collection

In reading various portions of the Express Working Form documentation, one may get the impression that the Working Form does some reasonably intelligent memory management. This is not entirely true. The NIST PDES Toolkit is primarily a research tool. This is especially true of the Express and STEP Working Forms. The Working Forms allocate huge chunks of memory without batting an eye, and often this memory is not released until an application exits. Hooks for doing memory management do exist (e.g., `OBJfree()` and reference counts), and some attempt is made to observe them, but this is not given high priority in the current implementation.

## 3.6

### Default Print Routines

The library provides default print routines. This is oriented towards producing human-readable text and can be overridden by defining a new subroutine by the same name. However, as is, it provides a reasonable means of interactively browsing through the Working Form, especially if the Working Form is 'broken', such as when Fed-X itself is being debugged.

The following discussion assumes you are printing a Fed-X object from within gdb, the GNU debugger.

Every class has a 'print' function

#### 3.6.1

##### Printing Unknown Objects

Thus, to print out an object, say:

```
p OBJprint (obj)
```

This is useful if you have no idea what the object is.

#### 3.6.2

##### Printing Known Objects or Specific Classes of Objects

If you know 'obj' is a scope (or is a subclass of scope), you can also just say:

```
p SCOPEprint (obj)
```

For example, you can print out just the scope of an entity as:

```
p SCOPEprint (entity)
```

Alternatively, if you already have a handle to the hidden structure, you can directly print it out as:

```
p SCOPE_print (scope)
```

(You can not print out the scope of an entity this way, since the hidden forms do not inherit anything by themselves.)

Dataless classes may not necessarily have a print function, but can use print functions defined for classes that have private data.

#### 3.6.3

##### Printing Specific Object Attributes

Each class has a special variable called 'X\_print' (for example 'scope\_print') which determines which attributes of the scope are printed. For example, if you want scope references to be printed, do:

```
set scope_print.references = 1  
set scope_print.self = 1
```

Element 'self' is 0 (no attributes), 1 (some), or 2 (all). By default, it is set to 1 for linked lists, dictionaries and symbols, and 0 for all other classes. By default, all other elements are set to 1 (which means print, 0 means don't print). If 'self' is 0, it is forced to 1 when printed by its high level print function. (In other words, `SCOPEprint (object)` will force the scope to be printed, while `OBJprint (object)` will print only if `scope_print` says so.)

Except for the 'self' element, element names are exactly the same names as the names used in the hidden types. Classes that have only one attribute use a common print structure type with only a 'self' element.)

For convenience, the prefix of the print structure (i.e., 'scope' in 'scope\_print' is the same as the prefix used in the low-level functions (e.g., 'aggr\_lit\_print' is used rather 'aggregate\_literal\_print').

### 3.6.4 Global Printing Options

The structure 'Print' provides some additional control. Attributes are as follows:

'header' controls whether header information such as class names are printed. By default, header is 1 meaning only the most specific class is described. 0 disables class descriptions, while 2 forces all class descriptions to be printed. Class specific data is printed after each class header.

'depth\_max' controls the depth of object recursion. By default, the depth is 2.

'debug' controls whether internal functioning of the print routines themselves are printed. This is only useful if you have some doubts about the correct functioning of the print routines. Incorrect function has always turned out to be the case of something else having sabotaged the environment, so this 'debug' element is more useful for reassuring yourself that the environment (stack, heap, whatever) has not been corrupted.

Other elements in 'Print' are of value only to the implementation.

### 3.6.5 Printing to a File

By default, output is printed to the standard output. To redirect this to a file, say:

```
p OBJprint_file("foo")
```

To redirect back to the standard output and close the current output file:

```
p OBJprint_file((char *)0)
```

## 4 Writing An Output Module

It is expected that a common use of the Express WF will be to build Express translators. The Fed-X control flow was designed with this application in mind. A programmer who wishes to build such a translator need only write an output module for the target language. We now turn to the topic of writing this output module. The end result of

the process described will be an object module (under Unix, a .o file) which can be loaded into Fed-X. This module contains a single entry point which traverses a given Schema and writes its output to a particular file.

The stylistic convention taken in the existing output modules, and which meshes most cleanly with the design of the Working Form data structures, is to define a procedure `FOOprint(Foo foo, FILE* file)` corresponding to each Working Form abstraction. Thus, `SCHEMAsprint(Schema schema, FILE* file)` is the conceptual entry point to the output module; an Algorithm is written by the call `ALGprint(Algorithm algorithm, FILE* file)`, etc. With this breakdown, most of the actual output is generated by the routines for Type, Entity, and other concrete Express constructs. The routines for Schema and Scope, on the other hand, control the traversal of the data structures, and produce little or no actual output. For this reason, it is probably useful to base new report generators on existing ones, copying the traversal logic wholesale and modifying only the routines for the concrete objects.

Note that the library has default definitions of object print routines, although they are primarily for the purpose of producing human-readable descriptions. These may be overridden by supplying new definitions as suggested above. Note, however, that overriding a built-in print routine may cause misbehavior of other built-in print routines which depend on it.

## 4.1 Layout of the C Source

The layout of the C source file for a report generator which will be dynamically loaded is of critical importance, due to the primitive level at which the load is carried out. The very first piece of C source in the file must be the `entry_point()` function, or the loader may find the wrong entry point to the file, resulting in mayhem. Only comments may precede this function; even an `#include` directive may throw off the loader. An output module is normally laid out as shown:

```
void
entry_point(void* schema, void* file)
{
    extern void print_file();
    print_file(schema, file);
}

#include "express.h"

... actual output routines . .

void
print_file(void* schema, void* file)
{
    print_file_header((Schema)schema,
```

```

        (FILE*)file);
SCHEMAsprint((Schema)schema, (FILE*)file);
print_file_trailer((Schema)schema,
        (FILE*)file);
}

```

The `print_file()` function will probably always be quite similar to the one shown, although in many cases, the file header and/or trailer may well be empty, eliminating the need for these calls. In this case, `SCHEMAsprint()` and `print_file()` will probably become interchangeable.

Having said all of the above about templates, code layout, and so forth, we add the following note: In the final analysis, the output module really is a free-form piece of C code. There is one and only one rule which must be followed, and this only if the report generator will be dynamically loaded: The entry point (according to the `a.out` format) to the `.o` file which is produced when the report generator is compiled must be appropriate to be called with a `Schema` and a `FILE*`. The simplest (and safest) way of doing this is to adhere strictly to the layout given, and write an `entry_point()` routine which jumps to the real (conceptual) entry point. But any other mechanism which guarantees this property may be used. Similarly, the layout of the rest of the code is purely conventional. There is no *a priori* reason to write one output routine per data structure, or to use the `print_file()` routine suggested. This approach has simply proved to work nicely for current and past report generators, and seems to provide the shortest path to a new output module. In other words, if you don't like the authors' coding style(s), feel free to use your own techniques.

## 4.2 Traversing a Schema

Following the one-routine-per-abstraction rule, there are two general classes of output routines. Those corresponding to primitive Express constructs (`ENTITYprint()`, `TYPEprint()`, `VARprint()`) will produce most of the actual output, while `SCOPEprint()` (and, to a lesser extent `SCHEMAsprint()`) will be responsible for traversing the instantiated working form. A typical definition for `SCOPEprint()` would be:

```

void
SCOPEprint(Scope scope, FILE* file)
{
    Linked_List list;

    list = SCOPEget_types(scope);
    LISTdo(list, type, Type)
        TYPEprint(type, file);
    LISTod;
    LISTfree(list);

    list = SCOPEget_entities(scope);

```

```

        .LISTdo(list, ent, Entity)
            ENTITYprint(ent, file);
        LISTTod;
        LISTfree(list);

        list = SCOPEget_algorithms(scope);
        LISTdo(list, alg, Algorithm)
            ALGprint(alg, file);
        LISTTod;
        LISTfree(list);

        list = SCOPEget_variables(scope);
        LISTdo(list, var, Variable)
            VARprint(var, file);
        LISTTod;
        LISTfree(list);

        list = SCOPEget_schemata(scope);
        LISTdo(list, schema, Schema)
            SCHEMAprint(schema, file);
        LISTTod;
        LISTfree(list);
    }
}

```

This function traverses the model from the outermost schema inward. All types, entities, algorithms, and variables in a schema are printed (in that order), followed by all definitions for any sub-schemas. The only traversal logic required in SCHEMAprint() is simply to call SCOPEprint().

An approach which is taken in the Fed-X-QDES output module is to divide the logical functionality of SCOPEprint() into two separate passes, implemented by functions SCOPEprint\_pass1() and SCOPEprint\_pass2(). The first pass prints all of the entity definitions, in superclass order (i.e., subclasses are not printed until after their superclasses), without attributes. This is necessary because of some difficulties with forward references in Smalltalk-80. The second pass then looks much like the sample definition of SCOPEprint() given above. This multi-pass strategy could also be used to print, for example, all of the type and entity definitions in the entire model, followed by all variable and algorithm definitions.

## 4.3 Working Form Routines

The remainder of this manual consists of specifications and brief descriptions of the access routines and associated error codes for the Express Working Form. Each subsection below corresponds to a module in the Working Form library. The Working Form Manager module is listed first, followed by the remaining data abstractions in alphabetical order.

The error codes are manipulated by the Error module [Clark90d]. Only error codes unique to each routine, are listed after each description.

## 4.4 Working Form Manager

**Type:** Express

**Procedure:** EXPRESSdump\_model

**Parameters:** Express model - Express model to dump

**Returns:** void

**Description:** Dump an Express model to `stderr`. This call is provided for debugging purposes.

**Procedure:** EXPRESSfree

**Parameters:** Express model - Express model to free

**Returns:** void

**Description:** Release an Express model. Indicates that the model is no longer used by the caller; if there are no other references to the model, all storage associated with it may be released.

**Procedure:** EXPRESSinitialize

**Parameters:** -- none --

**Returns:** void

**Description:** Initialize the Express package. This call in turn initializes all components of the Working Form package. Normally, it is called instead of calling all of the individual `XXXinitialize()` routines. In a typical Express (or STEP) translator, this function is called by the default `main()` provided in the Working Form library. Other applications should call it at initialization time.

**Procedure:** EXPRESSpass\_1

**Parameters:** FILE\* file - Express source file to parse

**Returns:** Express - resulting Working Form model

**Description:** Parse an Express source file into the Working Form. No symbol resolution is performed

**Procedure:** EXPRESSpass\_2

**Parameters:** Express model - Working Form model to resolve

**Returns:** void

**Description:** Perform symbol resolution on a loosely-coupled Working Form model (which was probably created by `EXPRESSpass_1()`).

**Procedure:** EXPRESSpass\_3

**Parameters:** Express model - Working Form model to report

**Returns:** FILE\* file - output file

**Returns:** void

**Description:** Invoke one (or more) report generator(s), according to the selected linkage mechanism.

**Procedure:** PASS2initialize  
**Parameters:** -- none --  
**Returns:** void  
**Description:** Initialize the Fed-X second pass.

## 4.5 Algorithm

**Type:** Algorithm  
**Supertype:** Scope  
**Subtypes:** Function, Procedure, Rule

**Procedure:** ALGget\_body  
**Parameters:** Algorithm algorithm - algorithm to examine  
**Returns:** Linked\_List - body of algorithm  
**Description:** Retrieve the code body of an algorithm. The elements of the list returned are Statements.

**Procedure:** ALGget\_name  
**Parameters:** Algorithm algorithm - algorithm to examine  
**Returns:** String - the name of the algorithm  
**Description:** Retrieve the name of an algorithm.

**Procedure:** ALGget\_parameters  
**Parameters:** Algorithm algorithm - algorithm to examine  
**Returns:** Linked\_List - formal parameter list  
**Description:** Retrieve the formal parameter list for an algorithm. When ALGget\_class(algorithm) == ALG\_RULE, the returned list contains the Entitys to which the rule applies. Otherwise, it contains Variables specifying the formal parameters to the function or procedure.

**Procedure:** ALGinitialize  
**Parameters:** -- none --  
**Returns:** void  
**Description:** Initialize the Algorithm module. This is called by EXPRESSinitialize(), and so normally need not be called individually.

**Procedure:** ALGprint  
**Parameters:** Algorithm  
**Returns:** void  
**Description:** Prints an algorithm. Exactly what is printed can be controlled by setting various elements of the variable alg\_print.

**Procedure:** ALGput\_body  
**Parameters:** Algorithm algorithm - algorithm to modify  
Linked\_List statements - body of algorithm  
**Returns:** void  
**Description:** Set the code body of an algorithm. The second parameter should be a list of Statements.

<b>Procedure:</b>	ALGput_name
<b>Parameters:</b>	Algorithm algorithm - algorithm to modify String name - new name for algorithm
<b>Returns:</b>	void
<b>Description:</b>	Set the name of an algorithm.
<b>Procedure:</b>	ALGput_parameters
<b>Parameters:</b>	Algorithm algorithm - algorithm to modify Linked_List list - formal parameters for this algorithm
<b>Returns:</b>	void
<b>Description:</b>	Set the formal parameter list of an algorithm. When ALGget_class(algorithm) == ALG_RULE, the formal parameters should be the Entitys to which the rule applies. Otherwise, they should be Variables.
<b>Procedure:</b>	ALGresolve
<b>Parameters:</b>	Algorithm algorithm - algorithm to resolve Scope scope - scope in which to resolve
<b>Returns:</b>	void
<b>Description:</b>	Resolve all references in an algorithm definition. This is called, in due course, by EXPRESSpass_2().
<b>Procedure:</b>	FUNCget_return_type
<b>Parameters:</b>	Function function - function to examine
<b>Returns:</b>	Type - function's return type
<b>Description:</b>	Return the type of the function.
<b>Procedure:</b>	FUNCprint
<b>Parameters:</b>	Function
<b>Returns:</b>	void
<b>Description:</b>	Prints a function. Exactly what is printed can be controlled by setting various elements of the variable func_print.
<b>Procedure:</b>	FUNCput_return_type
<b>Parameters:</b>	Function function - function to modify
<b>Returns:</b>	Type type - the function's return type
<b>Description:</b>	Set the return type of a function.
<b>Procedure:</b>	RULEget_where_clause
<b>Parameters:</b>	Rule rule - rule to examine
<b>Returns:</b>	Linked_List - list of rule's WHERE clause constraints
<b>Description:</b>	Return the where clause of a rule.
<b>Procedure:</b>	RULEprint
<b>Parameters:</b>	Rule
<b>Returns:</b>	void
<b>Description:</b>	Prints a rule. Exactly what is printed can be controlled by setting various elements of the variable rule_print.

**Procedure:** RULEput\_where\_clause  
**Parameters:** Rule rule - rule to modify  
**Returns:** Linked\_List where - list of WHERE clause constraints for rule  
**Description:** void  
Set the where clause of a rule

## 4.6 Case Item

**Type:** Case\_Item  
**Supertype:** Construct

**Procedure:** CASE\_ITcreate  
**Parameters:** Linked\_List of Expression labels - list of case labels  
Statement statement - statement associated with this branch  
Error\* errc - buffer for error code  
**Returns:** Case\_Item - the case item created  
**Description:** Create a new case item. If the 'labels' parameter is LIST\_NULL, a case item matching in the default case is created. Otherwise, the case item created will match when the case selector has the same value as any of the Expressions on the labels list.

**Procedure:** CASE\_ITget\_labels  
**Parameters:** Case\_Item item - case item to examine  
**Returns:** Linked\_List - list of case labels  
**Description:** Retrieve the list of label Expressions for which a case item matches. For an item which matches in the default case, LIST\_NULL is returned.

**Procedure:** CASE\_ITget\_statement  
**Parameters:** Case\_Item item - the case item to examine  
**Returns:** Statement - statement associated with this branch  
**Description:** Retrieve the statement to be executed when this case item is matched.

**Procedure:** CASE\_ITinitialize  
**Parameters:** -- none --  
**Returns:** void  
**Description:** Initialize the Case Item module. This is called by EXPRESSinitialize(), and so normally need not be called individually.

**Procedure:** CASE\_ITprint  
**Parameters:** Case\_Item  
**Returns:** void  
**Description:** Prints a Case\_Item. Exactly what is printed can be controlled by setting various elements of the variable case\_it\_print.

**Procedure:** CASE\_ITresolve  
**Parameters:** Case\_Item item - case item to resolve  
Scope scope - scope in which to resolve  
**Returns:** void  
**Description:** Resolve all symbol references in a case item. This is called, in due course, by EXPRESSpass\_2().

## 4.7 Constant

<b>Type:</b>	Constant
<b>Supertype:</b>	Symbol
<b>Procedure:</b>	CSTcreate
<b>Parameters:</b>	String name - name of new constant Type type - type of new constant Generic value - value for new constant
<b>Returns:</b>	Constant - the constant created
<b>Description:</b>	Create a new constant.
<b>Procedure:</b>	CSTget_name
<b>Parameters:</b>	Constant constant - constant to examine
<b>Returns:</b>	String - the name of the constant
<b>Description:</b>	Return the name of a constant.
<b>Procedure:</b>	CSTget_type
<b>Parameters:</b>	Constant constant - constant to examine
<b>Returns:</b>	Type - the type of the constant
<b>Description:</b>	Return the type of a constant.
<b>Procedure:</b>	CSTget_value
<b>Parameters:</b>	Constant constant - constant to examine
<b>Returns:</b>	Generic - the value of the constant
<b>Description:</b>	Return the value of a constant.
<b>Procedure:</b>	CSTinitialize
<b>Parameters:</b>	-- none --
<b>Returns:</b>	void
<b>Description:</b>	Initialize the Constant module. This is called by EXPRESSinitialize(), and so normally need not be called individually.
<b>Procedure:</b>	CSTprint
<b>Parameters:</b>	Constant
<b>Returns:</b>	void
<b>Description:</b>	Prints a Constant. Exactly what is printed can be controlled by setting various elements of the variable cst_print.
<b>Procedure:</b>	CSTput_name
<b>Parameters:</b>	Constant constant - constant to modify String - name for constant
<b>Returns:</b>	void
<b>Description:</b>	Set the name of a constant
<b>Procedure:</b>	CSTput_type
<b>Parameters:</b>	Constant constant - constant to modify Type - type for constant
<b>Returns:</b>	void
<b>Description:</b>	Set the type of a constant

**Procedure:** C\$Tput\_value  
**Parameters:** Constant constant - constant to modify  
 Generic - value of constant  
**Returns:** void  
**Description:** Set the value of a constant

## 4.8 Construct

<b>Type:</b>	Construct
<b>Supertype:</b>	-- none --
<b>Procedure:</b>	CONSTRget_line_number
<b>Parameters:</b>	Construct construct - construct to examine
<b>Returns:</b>	int - line number of construct
<b>Description:</b>	Return the line number of a construct.
<b>Procedure:</b>	CONSTRinitialize
<b>Parameters:</b>	-- none --
<b>Returns:</b>	void
<b>Description:</b>	Initialize the Construct module. This is called by EXPRESSinitialize(), and so normally need not be called individually.
<b>Procedure:</b>	CONSTRprint
<b>Parameters:</b>	Construct
<b>Returns:</b>	void
<b>Description:</b>	Prints a construct. Exactly what is printed can be controlled by setting various elements of the variable constr_print.
<b>Procedure:</b>	CONSTRput_line_number
<b>Parameters:</b>	Construct construct - construct to modify
<b>              </b>	int number - line number for construct
<b>Returns:</b>	void
<b>Description:</b>	Set a construct's line number.

## 4.9 Entity

<b>Type:</b>	Entity
<b>Supertype:</b>	Scope
<b>Procedure:</b>	ENTITYadd_attribute
<b>Parameters:</b>	Entity entity - entity to modify
<b>              </b>	Variable attribute - attribute to add
<b>Returns:</b>	void
<b>Description:</b>	Adds an attribute to the entity.
<b>Procedure:</b>	ENTITYadd_instance
<b>Parameters:</b>	Entity entity - entity to modify
<b>              </b>	Generic instance - new instance
<b>Returns:</b>	void
<b>Description:</b>	Adds an instance of the entity.

<b>Procedure:</b>	ENTITYdelete_instance
<b>Parameters:</b>	Entity entity - entity to modify Generic instance - instance to delete
<b>Returns:</b>	void
<b>Description:</b>	Deletes an instance of the entity.
<b>Procedure:</b>	ENTITYget_abstract
<b>Parameters:</b>	Entity
<b>Returns:</b>	Boolean
<b>Description:</b>	returns boolean defining when entity is abstract or not
<b>Procedure:</b>	ENTITYget_all_attributes
<b>Parameters:</b>	Entity entity - entity to examine
<b>Returns:</b>	Linked_List of Variable - all attributes of this entity
<b>Description:</b>	Retrieve the complete attribute list of an entity. The attributes are ordered as required by the STEP Physical File format [Part21]. This list should be LISTfree'd when no longer needed.
<b>Procedure:</b>	ENTITYget_attribute_offset
<b>Parameters:</b>	Entity entity - entity to examine Variable attribute - attribute to retrieve offset for
<b>Returns:</b>	int - offset to given attribute
<b>Description:</b>	Retrieve offset to an entity attribute. This offset takes into account all superclass of the entity:: it is computed by ENTITYget_initial_offset(entity) + VARget_offset(attribute). If the entity does not include the attribute, -1 is returned. This call should be preferred over ENTITYget_named_attribute_offset().
<b>Procedure:</b>	ENTITYget_attributes
<b>Parameters:</b>	Entity entity - entity to examine
<b>Returns:</b>	Linked_List of Variable - local attributes of this entity
<b>Description:</b>	Retrieve the local attribute list of an entity. The local attributes of an entity are those which are defined by the entity itself (rather than being inherited from supertypes). This list should be LISTfree'd when no longer needed.
<b>Procedure:</b>	ENTITYget_constraints
<b>Parameters:</b>	Entity entity - entity to examine
<b>Returns:</b>	Linked_List of Expression - this entity's constraints
<b>Description:</b>	Retrieve the list of constraints from an entity's "where" clause. This list should <u>not</u> be LISTfree'd.
<b>Procedure:</b>	ENTITYget_initial_offset
<b>Parameters:</b>	Entity entity - entity to examine
<b>Returns:</b>	int - number of inherited attributes
<b>Description:</b>	Retrieve the initial offset to an entity's local frame. This is the total number of explicit attributes inherited from supertypes.
<b>Procedure:</b>	ENTITYget_instances
<b>Parameters:</b>	Entity entity - entity to examine
<b>Returns:</b>	Linked_List - list of instances of the entity
<b>Description:</b>	Retrieve an entity's instance list. This list should <u>not</u> be LISTfree'd.

<b>Procedure:</b>	ENTITYget_mark
<b>Parameters:</b>	Entity entity - entity to examine
<b>Returns:</b>	int - entity's current mark
<b>Description:</b>	Retrieve an entity's mark. See ENTITYput_mark().
<b>Procedure:</b>	ENTITYget_name
<b>Parameters:</b>	Entity entity - entity to examine
<b>Returns:</b>	String - entity name
<b>Description:</b>	Return the name of an entity.
<b>Procedure:</b>	ENTITYget_named_attribute
<b>Parameters:</b>	Entity entity - entity to examine
	String name - name of attribute to retrieve
<b>Returns:</b>	Variable - the named attribute of this entity
<b>Description:</b>	Retrieve the definition of an entity attribute by name. If the entity has no attribute with the given name, VARIABLE_NULL is returned.
<b>Procedure:</b>	ENTITYget_named_attribute_offset
<b>Parameters:</b>	Entity entity - entity to examine
	String name - name of attribute for which to retrieve offset
<b>Returns:</b>	int - offset to named attribute of this entity
<b>Description:</b>	Retrieve the offset to an entity attribute by name. If the entity has no attribute with the given name, -1 is returned. This call is slower than ENTITYget_attribute_offset(), and so should be avoided when the actual attribute definition is already available.
<b>Procedure:</b>	ENTITYget_size
<b>Parameters:</b>	Entity entity - entity to examine
<b>Returns:</b>	int - storage size of instantiated entity
<b>Description:</b>	Compute the storage size of an instantiation of this entity. This is the total number of attributes which it contains.
<b>Procedure:</b>	ENTITYget_subtype
<b>Parameters:</b>	Entity
	String
<b>Returns:</b>	Entity
<b>Description:</b>	Given name, returns subtype
<b>Procedure:</b>	ENTITYget_subtype_expression
<b>Parameters:</b>	Entity entity - entity to examine
<b>Returns:</b>	Expression - immediate subtype expression
<b>Description:</b>	Retrieve the controlling expression for an entity's immediate subtype list.
<b>Procedure:</b>	ENTITYget_subtypes
<b>Parameters:</b>	Entity entity - entity to examine
<b>Returns:</b>	Linked_List of Entity - immediate subtypes of this entity
<b>Description:</b>	Retrieve a list of an entity's immediate subtypes.

<b>Procedure:</b>	ENTITYget_supertype
<b>Parameters:</b>	Entity String
<b>Returns:</b>	Entity
<b>Description:</b>	Given name, returns supertype
<b>Procedure:</b>	ENTITYget_supertypes
<b>Parameters:</b>	Entity entity - entity to examine
<b>Returns:</b>	Linked_List of Entity - immediate supertypes of this entity
<b>Description:</b>	Retrieve a list of an entity's immediate supertypes. This list should <u>not</u> be LISTfree'd.
<b>Procedure:</b>	ENTITYget_uniqueness_list
<b>Parameters:</b>	Entity entity - entity to examine
<b>Returns:</b>	Linked_List of Linked_List - this entity's uniqueness sets
<b>Description:</b>	Retrieve an entity's uniqueness list. Each element of this list is itself a list of Variables, specifying a uniqueness set for the entity. The uniqueness list should <u>not</u> be LISTfree'd, nor should any of the component lists.
<b>Procedure:</b>	ENTITYhas_immediate_subtype
<b>Parameters:</b>	Entity parent - entity to check children of Entity child - child to check for
<b>Returns:</b>	Boolean - is child a direct subtype of parent?
<b>Procedure:</b>	ENTITYhas_immediate_supertype
<b>Parameters:</b>	Entity child - entity to check parentage of Entity parent - parent to check for
<b>Returns:</b>	Boolean - is parent a direct supertype of child?
<b>Procedure:</b>	ENTITYhas_subtype
<b>Parameters:</b>	Entity parent - entity to check descendants of Entity child - child to check for
<b>Returns:</b>	Boolean - does parent's subclass tree include child?
<b>Procedure:</b>	ENTITYhas_supertype
<b>Parameters:</b>	Entity child - entity to check parentage of Entity parent - parent to check for
<b>Returns:</b>	Boolean - does child's superclass chain include parent?
<b>Procedure:</b>	ENTITYinitialize
<b>Parameters:</b>	-- none --
<b>Returns:</b>	void
<b>Description:</b>	Initialize the Entity module. This is called by EXPRESSinitialize(), and so normally need not be called individually.
<b>Procedure:</b>	ENTITYprint
<b>Parameters:</b>	Entity
<b>Returns:</b>	void
<b>Description:</b>	Prints an Entity. Exactly what is printed can be controlled by setting various elements of the variable entity_print.

<b>Procedure:</b>	ENTITYput_abstract
<b>Parameters:</b>	Entity Boolean
<b>Returns:</b>	void
<b>Description:</b>	Define an entity to be abstract or not.
<b>Procedure:</b>	ENTITYput_constraints
<b>Parameters:</b>	Entity entity - entity to modify Linked_List constraints - list of constraints which entity must satisfy
<b>Returns:</b>	void
<b>Description:</b>	Set the constraints on an entity. The elements of the constraints list should be Expressions of type TY_LOGICAL.
<b>Procedure:</b>	ENTITYput_inheritance_count
<b>Parameters:</b>	Entity entity - entity to modify int count - number of inherited attributes
<b>Returns:</b>	void
<b>Description:</b>	Set the number of attributes inherited by an entity. This should be computed automatically (perhaps only when needed), and this call removed. The count is currently computed by ENTITYresolve().
<b>Procedure:</b>	ENTITYput_mark
<b>Parameters:</b>	Entity entity - entity to modify int value - new mark for entity
<b>Returns:</b>	void
<b>Description:</b>	Set an entity's mark. This mark is used, for example, in SCOPE_dfs(), part of SCOPEget_entities_superclass_order(), to mark each entity as having been touched by the traversal.
<b>Procedure:</b>	ENTITYput_name
<b>Parameters:</b>	Entity entity - entity to modify String name - entity's name
<b>Returns:</b>	void
<b>Description:</b>	Set the name of an entity.
<b>Procedure:</b>	ENTITYput_subtypes
<b>Parameters:</b>	Entity entity - entity to modify Expression expression - controlling subtype expression
<b>Returns:</b>	void
<b>Description:</b>	Set the (immediate) subtypes list of an entity.
<b>Procedure:</b>	ENTITYput_supertypes
<b>Parameters:</b>	Entity entity - entity to modify Linked_List list - superclass entities
<b>Returns:</b>	void
<b>Description:</b>	Set the (immediate) supertype list of an entity. The elements of the list should be Entitys or (unresolved) Symbols.

**Procedure:** ENTITYput\_uniqueness\_list  
**Parameters:** Entity entity - entity to modify  
Linked\_List list - uniqueness list  
**Returns:** void  
**Description:** Set the uniqueness list of an entity. Each element of the uniqueness list should itself be a list of Variables and/or (unresolved) Symbols referencing entity attributes. Each of these sublists specifies a single uniqueness set for the entity.

**Procedure:** ENTITYresolve  
**Parameters:** Entity entity - entity to resolve  
**Returns:** void  
**Description:** Resolve all symbol references in an entity definition. This function is called, in due course, by EXPRESSpass\_2().

## 4.10 Expression

**Type:** Expression  
**Supertype:** Construct

**Private Type:** Ary\_Expression  
**Supertype:** Expression

**Type:** Binary\_Expression  
**Supertype:** Ary\_Expression

**Type:** Ternary\_Expression  
**Supertype:** Ary\_Expression

**Type:** Unary\_Expression  
**Supertype:** Ary\_Expression

**Type:** One\_Of\_Expression  
**Supertype:** Expression

**Type:** Function\_Call  
**Supertype:** One\_Of\_Expression

**Type:** Identifier  
**Supertype:** Expression

**Private Type:** Literal  
**Supertype:** Expression

**Type:** Aggregate\_Literal  
**Supertype:** Literal

**Type:** Binary\_Literal  
**Supertype:** Literal

**Type:** Integer\_Literal  
**Supertype:** Literal

<b>Type:</b>	Logical_Literal
<b>Supertype:</b>	Literal
<b>Type:</b>	Real_Literal
<b>Supertype:</b>	Literal
<b>Type:</b>	String_Literal
<b>Supertype:</b>	Literal
<b>Type:</b>	Query
<b>Supertype:</b>	Expression
<b>Constant:</b>	LITERAL_E - a real literal with the value 2.18281...
<b>Type:</b>	Real_Literal
<b>Constant:</b>	LITERAL_EMPTY_SET - a generic set literal representing the empty set
<b>Type:</b>	Aggregate_Literal
<b>Constant:</b>	LITERAL_INFINITY - a numeric literal representing infinity
<b>Type:</b>	Integer_Literal
<b>Constant:</b>	LITERAL_PI - a real literal with the value 3.1415...
<b>Type:</b>	Real_Literal
<b>Constant:</b>	LITERAL_ZERO - an integer literal with the value 0
<b>Type:</b>	Integer_Literal
<b>Procedure:</b>	AGGR_LITcreate
<b>Parameters:</b>	Type type - type of aggregate literal to be created Linked_List value - value for literal Error* errc - buffer for error code
<b>Returns:</b>	Aggregate_Literal - the literal created
<b>Description:</b>	Create an aggregate literal expression.
<b>Procedure:</b>	AGGR_LITget_value
<b>Parameters:</b>	Aggregate_Literal literal - aggregate literal to examine Error* errc - buffer for error code
<b>Returns:</b>	Linked_List of Generic - the literal's contents
<b>Description:</b>	Retrieve the value of an aggregate literal, as a list.
<b>Procedure:</b>	AGGR_LITprint
<b>Parameters:</b>	Aggregate_Literal
<b>Returns:</b>	void
<b>Description:</b>	Prints an Aggregate_Literal. Exactly what is printed can be controlled by setting various elements of the variable aggr_lit_print.
<b>Procedure:</b>	ARY_EXPget_operand
<b>Parameters:</b>	Ary_Expression operand
<b>Returns:</b>	Unary Expression - the expression created
<b>Description:</b>	Create a unary operation expression

<b>Procedure:</b>	ARY_EXPget_operator
<b>Parameters:</b>	Ary_Expression
<b>Returns:</b>	Op_Code
<b>Description:</b>	Return operator of expression
<b>Procedure:</b>	ARY_EXPprint
<b>Parameters:</b>	Ary_Expression
<b>Returns:</b>	void
<b>Description:</b>	Prints an Ary_Expression. Exactly what is printed can be controlled by setting various elements of the variable ary_exp_print.
<b>Procedure:</b>	ARY_EXPput_operand
<b>Parameters:</b>	Ary_Expression - Unary expression to modify
<b>Returns:</b>	Expression - Expression to become new operand
<b>Description:</b>	void Modifies the operand of a unary expression
<b>Procedure:</b>	BIN_EXPcreate
<b>Parameters:</b>	Op_Code op - operation
<b>Returns:</b>	Expression operand1 - first operand
<b>Description:</b>	Expression operand2 - second operand Error* errc - buffer for error code Binary_Expression - the expression created Create a binary operation expression.
<b>Procedure:</b>	BIN_EXPget_first_operand
<b>Parameters:</b>	Binary_Expression expression - expression to examine
<b>Returns:</b>	Expression - the first (left-hand) operand of the expression
<b>Description:</b>	Return first operand of binary expression.
<b>Procedure:</b>	BIN_EXPget_operator
<b>Parameters:</b>	Binary_Expression expression - expression to examine
<b>Returns:</b>	Op_Code - the operator invoked by the expression
<b>Description:</b>	Return operator of binary expression.
<b>Procedure:</b>	BIN_EXPget_second_operand
<b>Parameters:</b>	Binary_Expression expression - expression to examine
<b>Returns:</b>	Expression - the second (right-hand) operand of the expression
<b>Description:</b>	Return second operand of binary expression.
<b>Procedure:</b>	BIN_EXPprint
<b>Parameters:</b>	Bin_Expression
<b>Returns:</b>	void
<b>Description:</b>	Prints an Bin_Expression. Exactly what is printed can be controlled by setting various elements of the variable bin_exp_print.
<b>Procedure:</b>	BIN_LITcreate
<b>Parameters:</b>	Binary
<b>Returns:</b>	Error *
<b>Description:</b>	Binary_Literal Creates a binary literal

<b>Procedure:</b>	BIN_LITget_value
<b>Parameters:</b>	Binary_Literal
<b>Returns:</b>	Error *
<b>Description:</b>	Binary
	Returns the binary corresponding to the binary_literal
<b>Procedure:</b>	BIN_LITprint
<b>Parameters:</b>	Binary_Literal
<b>Returns:</b>	void
<b>Description:</b>	Prints an Binary_Literal. Exactly what is printed can be controlled by setting various elements of the variable bin_lit_print.
<b>Procedure:</b>	EXPas_string
<b>Parameters:</b>	Expression expression - expression to print as string
<b>Returns:</b>	String - string representation of expression
<b>Description:</b>	Generate the string representation of an expression. Only (qualified) identifiers are currently supported.
<b>Procedure:</b>	EXPget_integer_value
<b>Parameters:</b>	Expression expression - expression to evaluate
<b>Returns:</b>	Error* errc - buffer for error code
<b>Description:</b>	int - value of expression
	Compute the value of an integer expression. Currently, only integer literals can be evaluated; other classes of expressions evaluate to 0 and produce a warning message. EXPRESSION_NULL evaluates to 0, as well.
<b>Errors:</b>	ERROR_integer_expression_expected
<b>Procedure:</b>	EXPget_type
<b>Parameters:</b>	Expression expression - expression to examine
<b>Returns:</b>	Type - the type of the value computed by the expression
<b>Procedure:</b>	EXPinitialize
<b>Parameters:</b>	-- none --
<b>Returns:</b>	void
<b>Description:</b>	Initialize the Expression module. This is called by EXPRESSinitialize(), and so normally need not be called individually.
<b>Procedure:</b>	EXPprint
<b>Parameters:</b>	Expression
<b>Returns:</b>	void
<b>Description:</b>	Prints an Expression. Exactly what is printed can be controlled by setting various elements of the variable exp_print.
<b>Procedure:</b>	EXPput_type
<b>Parameters:</b>	Expression expression - expression to modify
<b>Returns:</b>	Type type - the type of result computed by the expression
<b>Description:</b>	Set the type of an expression. This call should actually be unnecessary: the type of an expression is derivable from its definition. While this is currently true in the case of literals, there are no rules in place for deriving the type from, for example, the return type of a function or an operator together with its operands.

<b>Procedure:</b>	EXPResolve
<b>Parameters:</b>	Expression expression - expression to resolve Scope scope - scope in which to resolve
<b>Returns:</b>	void
<b>Description:</b>	Resolve all symbol references in an expression. This is called, in due course, by EXPRESSto_pass_2().
<b>Procedure:</b>	EXPResolve_qualification
<b>Parameters:</b>	Expression expression - expression to resolve Scope scope - scope in which to resolve Error* errc - buffer for error code
<b>Returns:</b>	Symbol - the symbol referenced by the expression
<b>Description:</b>	Retrieves the symbol definition referenced by a (possibly qualified) identifier.
<b>Procedure:</b>	FCALLcreate
<b>Parameters:</b>	Algorithm algorithm - algorithm invoked by expression Linked_List parameters - actual parameters to function call Error* errc - buffer for error code
<b>Returns:</b>	Function_Call - the function call created
<b>Description:</b>	Create a function call expression. -- none --
<b>Procedure:</b>	FCALLget_algorithm
<b>Parameters:</b>	Function_Call expression - function call expression to examine
<b>Returns:</b>	Algorithm - the algorithm invoked by the function call
<b>Description:</b>	Retrieves the algorithm of the function call.
<b>Procedure:</b>	FCALLget_parameters
<b>Parameters:</b>	Function_Call expression - function call expression to examine
<b>Returns:</b>	Linked_List of Expression - list of actual parameters
<b>Description:</b>	Retrieve the actual parameter Expressions from a function call expression.
<b>Procedure:</b>	FCALLprint
<b>Parameters:</b>	Function_Call
<b>Returns:</b>	void
<b>Description:</b>	Prints a Function_Call. Exactly what is printed can be controlled by setting various elements of the variable fcall_print.
<b>Procedure:</b>	FCALLput_algorithm
<b>Parameters:</b>	Function_Call expression - function call expression to modify Algorithm algorithm - algorithm invoked by expression
<b>Returns:</b>	void
<b>Description:</b>	Set the algorithm invoked by a function call expression.
<b>Procedure:</b>	FCALLput_parameters
<b>Parameters:</b>	Function_Call expression - function call expression to modify Linked_List parameters - list of actual parameters
<b>Returns:</b>	void
<b>Description:</b>	Set the actual parameter list to a function call expression. The elements of the parameter list should be Expressions. The types of the actual parameters currently are not verified against the formal parameter list of the called algorithm.

<b>Procedure:</b>	IDENTcreate
<b>Parameters:</b>	Symbol ident - identifier referenced by expression Error* errc - buffer for error code
<b>Returns:</b>	Identifier - the identifier expression created
<b>Description:</b>	Create a simple identifier expression.
<b>Procedure:</b>	IDENTget_identifier
<b>Parameters:</b>	Identifier expression - expression to examine
<b>Returns:</b>	Symbol - the identifier referenced in the expression
<b>Procedure:</b>	IDENTprint
<b>Parameters:</b>	Identifier
<b>Returns:</b>	void
<b>Description:</b>	Prints an Identifier. Exactly what is printed can be controlled by setting various elements of the variable ident_print.
<b>Procedure:</b>	IDENTput_identifier
<b>Parameters:</b>	Identifier expression - identifier expression to modify
<b>Returns:</b>	Symbol identifier - the referent of the identifier
<b>Description:</b>	void
<b>Description:</b>	Set the referent of an identifier expression.
<b>Procedure:</b>	INT_LITcreate
<b>Parameters:</b>	Integer value - value for literal Error* errc - buffer for error code
<b>Returns:</b>	Integer_Literal - the literal created
<b>Description:</b>	Create an integer literal expression.
<b>Procedure:</b>	INT_LITget_value
<b>Parameters:</b>	Integer_Literal literal - integer literal to examine Error* errc - buffer for error code
<b>Returns:</b>	Integer - the literal's value
<b>Procedure:</b>	INT_LITprint
<b>Parameters:</b>	Integer_Literal
<b>Returns:</b>	void
<b>Description:</b>	Prints an Integer_Literal. Exactly what is printed can be controlled by setting various elements of the variable int_lit_print.
<b>Procedure:</b>	LOG_LITcreate
<b>Parameters:</b>	Logical value - value for literal Error* errc - buffer for error code
<b>Returns:</b>	Logical_Literal - the literal created
<b>Description:</b>	Create a logical literal expression.
<b>Procedure:</b>	LOG_LITget_value
<b>Parameters:</b>	Logical_Literal literal - logical literal to examine Error* errc - buffer for error code
<b>Returns:</b>	Logical - the literal's value

<b>Procedure:</b>	LOG_LITprint
<b>Parameters:</b>	Logical_Literal
<b>Returns:</b>	void
<b>Description:</b>	Prints a Logical_Literal. Exactly what is printed can be controlled by setting various elements of the variable log_lit_print.
<b>Procedure:</b>	ONEOFcreate
<b>Parameters:</b>	Linked_List selections - list of selections for oneof() Error* errc - buffer for error code
<b>Returns:</b>	One_Of_Expression - the oneof expression created
<b>Description:</b>	Create a oneof() expression.
<b>Procedure:</b>	ONEOFget_selections
<b>Parameters:</b>	One_Of_Expression expression - expression to examine
<b>Returns:</b>	Linked_List of Expression - list of selections for oneof()
<b>Procedure:</b>	ONEOFprint
<b>Parameters:</b>	One_Of_Expression
<b>Returns:</b>	void
<b>Description:</b>	Prints a One_Of_Expression. Exactly what is printed can be controlled by setting various elements of the variable oneof_print.
<b>Procedure:</b>	ONEOFput_selections
<b>Parameters:</b>	One_Of_Expression expression - expression to modify Linked_List selections - list of selections for oneof()
<b>Returns:</b>	void
<b>Description:</b>	Set the list of selections for a oneof() expression.
<b>Procedure:</b>	opcode_print
<b>Parameters:</b>	Op_Code
<b>Returns:</b>	void
<b>Description:</b>	Despite the name, this function returns a string describing the opcode.
<b>Procedure:</b>	OPget_number_of_operands
<b>Parameters:</b>	Op_Code operation - the opcode to query
<b>Returns:</b>	int - number of operands required by this operator.
<b>Procedure:</b>	QUERYcreate
<b>Parameters:</b>	String ident - local identifier for source elements Expression source - source aggregate to query Expression discriminant - discriminating expression for query Error* errc - buffer for error code
<b>Returns:</b>	Query - the query expression created
<b>Description:</b>	Create a query expression.
<b>Procedure:</b>	QUERYget_discriminant
<b>Parameters:</b>	Query expression - query expression to examine
<b>Returns:</b>	Expression - the discriminant expression
<b>Description:</b>	Retrieves the discriminant expression from a query expression. The discriminant expresses the query criteria.

<b>Procedure:</b>	QUERYget_source
<b>Parameters:</b>	Query expression - query expression to examine
<b>Returns:</b>	Expression - the source aggregation
<b>Description:</b>	Retrieves the expression which computes the aggregation against which a query will be applied.
<b>Procedure:</b>	QUERYget_variable
<b>Parameters:</b>	Query expression - query expression to examine
<b>Returns:</b>	Variable - the local iteration variable of the query
<b>Procedure:</b>	QUERYprint
<b>Parameters:</b>	Query Expression
<b>Returns:</b>	void
<b>Description:</b>	Prints a Query Expression. Exactly what is printed can be controlled by setting various elements of the variable query_print.
<b>Procedure:</b>	REAL_LITcreate
<b>Parameters:</b>	Real value - value for literal
	Error* errc - buffer for error code
<b>Returns:</b>	Real_Literal - the literal created
<b>Description:</b>	Create a real literal expression.
<b>Procedure:</b>	REAL_LITget_value
<b>Parameters:</b>	Real_Literal literal - real literal to examine
	Error* errc - buffer for error code
<b>Returns:</b>	Real - the literal's value
<b>Procedure:</b>	REAL_LITprint
<b>Parameters:</b>	Real_Literal
<b>Returns:</b>	void
<b>Description:</b>	Prints a Real_Literal. Exactly what is printed can be controlled by setting various elements of the variable real_lit_print.
<b>Procedure:</b>	STR_LITcreate
<b>Parameters:</b>	String value - value for literal
	Error* errc - buffer for error code
<b>Returns:</b>	String_Literal - the literal created
<b>Description:</b>	Create a string literal expression.
<b>Procedure:</b>	STR_LITget_value
<b>Parameters:</b>	String_Literal literal - string literal to examine
	Error* errc - buffer for error code
<b>Returns:</b>	String - the literal's value
<b>Procedure:</b>	STR_LITprint
<b>Parameters:</b>	String_Literal
<b>Returns:</b>	void
<b>Description:</b>	Prints a String_Literal. Exactly what is printed can be controlled by setting various elements of the variable str_lit_print.

**Procedure:** TERN\_EXPcreate  
**Parameters:** Op\_Code  
 Expression  
 Expression  
 Expression  
 Error \*

**Returns:** Ternary\_Expression  
**Description:** Creates and returns a ternary expression

**Procedure:** TERN\_EXPget\_second\_operand  
**Parameters:** Ternary\_Expression  
**Returns:** Expression  
**Description:** Returns second operand of a ternary expression

**Procedure:** TERN\_EXPget\_third\_operand  
**Parameters:** Ternary\_Expression  
**Returns:** Expression  
**Description:** Returns third operand of a ternary expression

**Procedure:** TERN\_EXPprint  
**Parameters:** Ternary\_Expression  
**Returns:** void  
**Description:** Prints a Ternary\_Expression. Exactly what is printed can be controlled by setting various elements of the variable term\_exp\_print.

**Procedure:** UN\_EXPcreate  
**Parameters:** Op\_Code op - operation  
 Expression operand - operand  
 Error\* errc - buffer for error code

**Returns:** Unary\_Expression - the expression created  
**Description:** Create a unary operation expression.

**Procedure:** UN\_EXPget\_operand  
**Parameters:** Unary\_Expression expression - expression to examine  
**Returns:** Expression - the operand of the expression

**Procedure:** UN\_EXPget\_operator  
**Parameters:** Unary\_Expression expression - expression to examine  
**Returns:** Op\_Code - the operator invoked by the expression

## 4.11 Loop Control

**Type:** Loop\_Control  
**Supertype:** Construct

**Type:** Increment\_Control  
**Supertype:** Loop\_Control

**Private Type:** Conditional\_Control  
**Supertype:** Loop\_Control

<b>Type:</b>	Until_Control
<b>Supertype:</b>	Conditional_Control
<b>Type:</b>	While_Control
<b>Supertype:</b>	Conditional_Control
<b>Procedure:</b>	INCR_CTLcreate
<b>Parameters:</b>	Expression control - controlling expression Expression start - initial value Expression end - terminal value Expression increment - amount by which to increment Error* errc - buffer for error code
<b>Returns:</b>	Increment_Control - the loop control created
<b>Procedure:</b>	INCR_CTLprint
<b>Parameters:</b>	Increment_Control
<b>Returns:</b>	void
<b>Description:</b>	Prints an Increment_Control. Exactly what is printed can be controlled by setting various elements of the variable incr_ctl_print.
<b>Procedure:</b>	UNTILcreate
<b>Parameters:</b>	Expression control - termination condition Error* errc - buffer for error code
<b>Returns:</b>	Until - the loop control created
<b>Requires:</b>	OBJis_kind_of(EXPget_type(control), Class_Logical_Type)
<b>Errors:</b>	ERROR_control_boolean_expected - controlling expression is not logical
<b>Procedure:</b>	WHILEcreate
<b>Parameters:</b>	Expression control - continuation condition Error* errc - buffer for error code
<b>Returns:</b>	While - the loop control created
<b>Requires:</b>	OBJis_kind_of(EXPget_type(control), Class_Logical_Type)
<b>Errors:</b>	ERROR_control_boolean_expected - controlling expression is not logical
<b>Procedure:</b>	LOOP_CTLget_controlling_expression
<b>Parameters:</b>	Loop_Control control - loop control to examine
<b>Returns:</b>	Expression - controlling expression
<b>Description:</b>	Retrieve a loop control's controlling expression. For while and until controls, this is the termination or continuation condition, respectively. For iteration and set scan controls, this is the expression which receives successive values in the iteration.
<b>Procedure:</b>	LOOP_CTLprint
<b>Parameters:</b>	Loop_Control
<b>Returns:</b>	void
<b>Description:</b>	Prints a Loop_Control. Exactly what is printed can be controlled by setting various elements of the variable loop_ctl_print.
<b>Procedure:</b>	INCR_CTLget_final
<b>Parameters:</b>	Increment_Control control - increment control to examine
<b>Returns:</b>	Expression - terminal value for controlling expression
<b>Description:</b>	Retrieve the final value from an increment control.

<b>Procedure:</b>	INCR_CTLget_increment
<b>Parameters:</b>	Increment_Control control - increment control to examine
<b>Returns:</b>	Expression - amount to increment by on each iteration
<b>Description:</b>	Retrieve the increment expression from an increment control.
<b>Procedure:</b>	INCR_CTLget_start
<b>Parameters:</b>	Increment_Control control - increment control to examine
<b>Returns:</b>	Expression - initial expression for controlling expression
<b>Description:</b>	Retrieve the initial value from an increment control.
<b>Procedure:</b>	LOOP_CTLinitialize
<b>Parameters:</b>	-- none --
<b>Returns:</b>	void
<b>Description:</b>	Initialize the Loop Control module. This is called by EXPRESSinitialize(), and so normally need not be called individually.
<b>Procedure:</b>	LOOP_CTLresolve
<b>Parameters:</b>	Loop_Control control - control to resolve
<b>Returns:</b>	Scope scope - scope in which to resolve
<b>Description:</b>	void
<b>Description:</b>	Resolve all symbol references in a loop control. This is called, in due course, by EXPRESSpass_2().

## 4.12 Reference

<b>Procedure:</b>	REFERENCEresolve
<b>Parameters:</b>	Scope
<b>Returns:</b>	void
<b>Description:</b>	resolves all references in a scope.

## 4.13 Schema

<b>Type:</b>	Schema
<b>Supertype:</b>	Scope
<b>Type:</b>	Schemas
<b>Supertype:</b>	Dictionary
<b>Procedure:</b>	SCHEMAdump
<b>Parameters:</b>	String name - name of schema to dump
<b>Returns:</b>	FILE* file - file to dump to
<b>Description:</b>	Dump a schema to a file. This function is provided for debugging purposes.

<b>Procedure:</b>	SCHEMAGet_name
<b>Parameters:</b>	Schema schema - schema to examine
<b>Returns:</b>	String - the schema's name
<b>Procedure:</b>	SCHEMAinitialize
<b>Parameters:</b>	-- none --
<b>Returns:</b>	void
<b>Description:</b>	Initialize the Schema module. This is called by EXPRESSinitialize(), and so normally need not be called individually.
<b>Procedure:</b>	SCHEMResolve
<b>Parameters:</b>	Schema schema - schema to resolve
	Schemas schemas - all schemas in the Express file
<b>Returns:</b>	void
<b>Description:</b>	Resolve all symbol references within a schema. In order to avoid problems due to references to as-yet-unresolved symbols, schema resolution is broken into two passes, which are implemented by SCHEMResolve_pass1() and SCHEMResolve_pass2(). These two are called in turn by SCHEMResolve().

## 4.14 Scope

<b>Type:</b>	Scope
<b>Supertype:</b>	Symbol
<b>Procedure:</b>	SCOPEadd_reference
<b>Parameters:</b>	Scope Linked_List
<b>Returns:</b>	void
<b>Description:</b>	Adds a list of references (from one REFERENCE statement) to an entity.
<b>Procedure:</b>	SCOPEadd_use
<b>Parameters:</b>	Scope Linked_List
<b>Returns:</b>	void
<b>Description:</b>	Adds a list of references (from one USE statement) to an entity.
<b>Procedure:</b>	SCOPEadd_superscope
<b>Parameters:</b>	Scope scope - scope to modify Scope parent - additional parent scope
<b>Returns:</b>	void
<b>Description:</b>	Adds an immediate parent to a scope.
<b>Procedure:</b>	SCOPEcreate
<b>Parameters:</b>	Scope scope - next higher scope
<b>Returns:</b>	Scope - the scope created
<b>Description:</b>	Create an empty scope. Note that the connection between this new scope and its parent (the sole parameter to this call) is uni-directional: the parent does not immediately know about the child.

<b>Procedure:</b>	SCOPEdefine_symbol
<b>Parameters:</b>	Scope scope - scope in which to define symbol Symbol symdef - new symbol definition Error* errc - buffer for error code
<b>Returns:</b>	void
<b>Description:</b>	Define a symbol in a scope.
<b>Errors:</b>	Reports all errors directly, so only ERROR_subordinate_failed is propagated.
<b>Procedure:</b>	SCOPEdump
<b>Parameters:</b>	Scope scope - scope to dump FILE* file - file stream to dump to
<b>Returns:</b>	void
<b>Description:</b>	Dump a schema to a file. This function is provided for debugging purposes.
<b>Procedure:</b>	SCOPEget_algorithms
<b>Parameters:</b>	Scope scope - scope to examine
<b>Returns:</b>	Linked_List - list of locally defined algorithms
<b>Description:</b>	Retrieve a list of the algorithms defined locally in a scope. The elements of this list are Algorithms. The list should be LISTfree'd when no longer needed.
<b>Procedure:</b>	SCOPEget_constants
<b>Parameters:</b>	Scope scope - scope to examine
<b>Returns:</b>	Linked_List - list of locally defined constants
<b>Description:</b>	Retrieve a list of the constants defined locally in a scope. The elements of this list are Constants. The list should be LISTfree'd when no longer needed.
<b>Procedure:</b>	SCOPEget_entities
<b>Parameters:</b>	Scope scope - scope to examine
<b>Returns:</b>	Linked_List - list of locally defined entities
<b>Description:</b>	Retrieve a list of the entities defined locally in a scope. The elements of this list are Entitys. The list should be LISTfree'd when no longer needed. This function is considerably faster than SCOPEget_entities_superclass_order(), and should be used whenever the order of the entities on the list is not important.
<b>Procedure:</b>	SCOPEget_entities_superclass_order
<b>Parameters:</b>	Scope scope - scope to examine
<b>Returns:</b>	Linked_List - list of locally defined entities in superclass order
<b>Description:</b>	Retrieve a list of the entities defined locally in a scope. The elements of this list are Entitys. The list should be LISTfree'd when no longer needed. The list returned is ordered such that each entity appears before all of its subtypes.
<b>Procedure:</b>	SCOPEget_imports
<b>Parameters:</b>	Scope scope - scope to examine
<b>Returns:</b>	Linked_List - 'assumed' schemata
<b>Description:</b>	Retrieve a list of the schemata assumed in a scope. The elements of this list are Schemas. The list should <u>not</u> be LISTfree'd.
<b>Procedure:</b>	SCOPEget_references
<b>Parameters:</b>	Scope
<b>Returns:</b>	Dictionary
<b>Description:</b>	All the references (from all the REFERENCE statements) of an entity.

<b>Procedure:</b>	SCOPEget_resolved
<b>Parameters:</b>	Scope scope - scope to examine
<b>Returns:</b>	Boolean - has this scope been resolved?
<b>Description:</b>	Check whether symbol references in a scope have been resolved.
<b>Procedure:</b>	SCOPEget_superscopes
<b>Parameters:</b>	Scope scope - scope to examine
<b>Returns:</b>	Linked_List - list of next outer (containing) scopes
<b>Description:</b>	Retrieve a list of a scope's parent scope.
<b>Procedure:</b>	SCOPEget_types
<b>Parameters:</b>	Scope scope - scope to examine
<b>Returns:</b>	Linked_List - list of locally defined types
<b>Description:</b>	Retrieve a list of the types defined locally in a scope. The elements of this list are Types. The list should be LISTfree'd when no longer needed.
<b>Procedure:</b>	SCOPEget_uses
<b>Parameters:</b>	Scope
<b>Returns:</b>	Linked_List
<b>Description:</b>	Returns a list of all references (from USE statements) from an entity.
<b>Procedure:</b>	SCOPEget_variables
<b>Parameters:</b>	Scope scope - scope to examine
<b>Returns:</b>	Linked_List - list of locally defined variables
<b>Description:</b>	Retrieve a list of the variables defined locally in a scope. The elements of this list are Variables. The list should be LISTfree'd when no longer needed.
<b>Procedure:</b>	SCOPEinitialize
<b>Parameters:</b>	-- none --
<b>Returns:</b>	void
<b>Description:</b>	Initialize the Scope module. This is called by EXPRESSinitialize(), and so normally need not be called individually.
<b>Procedure:</b>	SCOPElookup
<b>Parameters:</b>	Scope scope - scope in which to look up name String name - name to look up Boolean walk - look in parent and imported scopes? Error* errc - buffer for error code
<b>Returns:</b>	Symbol - definition of name in scope
<b>Description:</b>	Retrieve a name's definition in a scope. If the scope does not define the name, the parent scopes are successively queried. If no definition is found, SYMBOL_NULL is returned.
<b>Errors:</b>	ERROR_UNDEFINED_IDENTIFIER - no definition was found
<b>Procedure:</b>	SCOPEprint
<b>Parameters:</b>	Scope
<b>Returns:</b>	void
<b>Description:</b>	Prints a Scope. Exactly what is printed can be controlled by setting various elements of the variable scope_print.

<b>Procedure:</b>	SCOPEput_resolved
<b>Parameters:</b>	Scope scope - scope to modify
<b>Returns:</b>	void
<b>Description:</b>	Set the 'resolved' flag for a scope. This normally should only be called by SCOPEResolve(), which actually resolves the scope.
<b>Procedure:</b>	SCOPEResolve
<b>Parameters:</b>	Scope scope - scope to resolve Schemas schemas - all conceptual schemas in the express file
<b>Returns:</b>	void
<b>Description:</b>	Resolve all symbol references in a scope. In order to avoid problems due to references to as-yet-unresolved symbols, scope resolution is broken into two passes, which are implemented by SCOPEResolve_pass1() and SCOPEResolve_pass2(). These two are called in turn by SCOPEResolve().

## 4.15 Statement

<b>Private Type:</b>	Statement
<b>Supertype:</b>	Construct
<b>Type:</b>	Assignment
<b>Supertype:</b>	Statement
<b>Type:</b>	Compound_Statement
<b>Supertype:</b>	Statement
<b>Type:</b>	Conditional
<b>Supertype:</b>	Statement
<b>Type:</b>	Loop
<b>Supertype:</b>	Statement
<b>Type:</b>	Procedure_Call
<b>Supertype:</b>	Statement
<b>Type:</b>	Return_Statement
<b>Supertype:</b>	Statement
<b>Type:</b>	With_Statement
<b>Supertype:</b>	Statement
<b>Procedure:</b>	ASSIGNcreate
<b>Parameters:</b>	Expression lhs - the left-hand-side of the assignment Expression rhs - the right-hand-side of the assignment Error* errc - buffer for error code
<b>Returns:</b>	Assignment - the assignment statement created
<b>Description:</b>	Create an assignment statement.

<b>Procedure:</b>	A\$SIGNget_lhs
<b>Parameters:</b>	Assignment statement - statement to examine
<b>Returns:</b>	Expression - left-hand-side of assignment statement
<b>Description:</b>	Return left-hand-side of the assignment statement.
<b>Procedure:</b>	ASSIGNget_rhs
<b>Parameters:</b>	Assignment statement - statement to examine
<b>Returns:</b>	Expression - right-hand-side of assignment statement
<b>Description:</b>	Return right-hand-side of the assignment statement.
<b>Procedure:</b>	ASSIGNprint
<b>Parameters:</b>	Assignment statement
<b>Returns:</b>	void
<b>Description:</b>	Prints an assignment statement. Exactly what is printed can be controlled by setting various elements of the variable assign_print.
<b>Procedure:</b>	CASEcreate
<b>Parameters:</b>	Expression selector - expression to case on Linked_List case - list of case branches Error* errc - buffer for error code
<b>Returns:</b>	Case_Statement - the case statement created
<b>Description:</b>	Create a case statement. The elements of the case branch list should be Case_Items.
<b>Procedure:</b>	CASEget_items
<b>Parameters:</b>	Case_Statement statement - statement to examine
<b>Returns:</b>	Linked_List - case branches
<b>Description:</b>	Retrieve a list of the branches in a case statement. The elements of this list are Case_Items.
<b>Procedure:</b>	CASEget_selector
<b>Parameters:</b>	Case_Statement statement - statement to examine
<b>Returns:</b>	Expression - the selector for the case statement
<b>Description:</b>	Retrieve the selector from a case statement. This is the expression whose value is compared to each case label in turn.
<b>Procedure:</b>	CASEprint
<b>Parameters:</b>	Case_Statement
<b>Returns:</b>	void
<b>Description:</b>	Prints a case statement. Exactly what is printed can be controlled by setting various elements of the variable case_print.
<b>Procedure:</b>	COMP_STMTcreate
<b>Parameters:</b>	Linked_List statements - list of compound statement elements Error* errc - buffer for error code
<b>Returns:</b>	Compound_Statement - the compound statement created
<b>Description:</b>	Create a compound statement. The elements of the statements list should be Statements, in the order they appear in the compound statement to be represented.
<b>Procedure:</b>	COMP_STMTget_items
<b>Parameters:</b>	Compound_Statement statement - statement to examine
<b>Returns:</b>	Linked_List - list of statements in compound
<b>Description:</b>	Retrieve a list of the Statements comprising a compound statement.

<b>Procedure:</b>	COMP_STMTprint
<b>Parameters:</b>	Compound_Statement
<b>Returns:</b>	void
<b>Description:</b>	Prints a compound statement. Exactly what is printed can be controlled by setting various elements of the variable <code>comp_stmt_print</code> .
<b>Procedure:</b>	CONDcreate
<b>Parameters:</b>	Expression test - the condition for the if Statement then - code executed when test == true Statement otherwise - code executed when test == false Error* errc - buffer for error code
<b>Returns:</b>	Conditional - the if statement created
<b>Description:</b>	Create an if statement. For a simple <code>if .. then ..</code> with no else clause, set the third parameter to <code>STATEMENT_NULL</code> .
<b>Procedure:</b>	CONDget_else_clause
<b>Parameters:</b>	Conditional statement - statement to examine
<b>Returns:</b>	Statement - code for 'else' branch
<b>Procedure:</b>	CONDget_condition
<b>Parameters:</b>	Conditional statement - statement to examine
<b>Returns:</b>	Expression - the test condition
<b>Procedure:</b>	CONDget_then_clause
<b>Parameters:</b>	Conditional statement - statement to examine
<b>Returns:</b>	Statement - code for 'then' branch
<b>Procedure:</b>	CONDprint
<b>Parameters:</b>	Conditional statement
<b>Returns:</b>	void
<b>Description:</b>	Prints a conditional statement. Exactly what is printed can be controlled by setting various elements of the variable <code>cond_print</code> .
<b>Procedure:</b>	LOOPcreate
<b>Parameters:</b>	Linked_List controls - list of controls for the loop Statement body - statement to be repeated Error* errc - buffer for error code
<b>Returns:</b>	Loop - the loop statement created
<b>Description:</b>	Create a loop statement. The elements of the controls list should be <code>Loop_Controls</code> .
<b>Procedure:</b>	LOOPget_body
<b>Parameters:</b>	Loop statement - statement to examine
<b>Returns:</b>	Statement - the body of the loop
<b>Description:</b>	Retrieve the body (repeated portion) of a loop statement
<b>Procedure:</b>	LOOPget_controls
<b>Parameters:</b>	Loop statement - statement to examine
<b>Returns:</b>	Linked_List - list of loop controls
<b>Description:</b>	Retrieve a list of a loop statement's controls. The elements of this list are <code>Loop_Controls</code> .

<b>Procedure:</b>	LOOPprint
<b>Parameters:</b>	Loop statement
<b>Returns:</b>	void
<b>Description:</b>	Prints a loop statement. Exactly what is printed can be controlled by setting various elements of the variable loop_print.
<b>Procedure:</b>	PCALLcreate
<b>Parameters:</b>	Procedure procedure - procedure called by statement Linked_List parameters - list of actual parameters Error* errc - buffer for error code
<b>Returns:</b>	Procedure_Call - the procedure call created
<b>Description:</b>	Create a procedure call statement. The elements of the actual parameter list should be Expressions which compute the values to be passed to the procedure.
<b>Procedure:</b>	PCALLget_procedure
<b>Parameters:</b>	Procedure_Call statement - statement to examine
<b>Returns:</b>	Procedure - procedure called by this statement
<b>Description:</b>	Retrieve the procedure called by a procedure call statement.
<b>Procedure:</b>	PCALLget_parameters
<b>Parameters:</b>	Procedure_Call statement - statement to examine
<b>Returns:</b>	Linked_List - actual parameters to this call
<b>Description:</b>	Retrieve the actual parameters for a procedure call statement. The elements of this list are Expressions which compute the values to be passed to the called routine.
<b>Procedure:</b>	PCALLprint
<b>Parameters:</b>	Procedure_Call statement
<b>Returns:</b>	void
<b>Description:</b>	Prints a Procedure_Call statement. Exactly what is printed can be controlled by setting various elements of the variable pcall_print.
<b>Procedure:</b>	PCALLput_procedure
<b>Parameters:</b>	Procedure_Call statement - statement to modify Procedure procedure - definition of called procedure
<b>Returns:</b>	void
<b>Description:</b>	Set the actual procedure called by a procedure call statement. If a procedure stub (unresolved Symbol) is present in the statement, it is replaced such that all references remain valid.
<b>Procedure:</b>	RETcreate
<b>Parameters:</b>	Expression expression - expression to compute return value Error* errc - buffer for error code
<b>Returns:</b>	Return_Statement - the return statement created
<b>Description:</b>	Create a return statement.
<b>Procedure:</b>	RETget_expression
<b>Parameters:</b>	Return_Statement statement - statement to examine
<b>Returns:</b>	Expression - expression returned by this statement
<b>Description:</b>	Retrieve the expression whose value is computed and returned by a return statement.

**Procedure:** RETprint  
**Parameters:** Return statement  
**Returns:** void  
**Description:** Prints a Return statement. Exactly what is printed can be controlled by setting various elements of the variable `return_print`.

**Procedure:** STMTinitialize  
**Parameters:** -- none --  
**Returns:** void  
**Description:** Initialize the Statement module. This is called by `EXPRESSinitialize()`, and so normally need not be called individually.

**Procedure:** STMTresolve  
**Parameters:** Statement statement - statement to resolve  
**Returns:** void  
**Description:** Resolve all symbol references in a statement. This is called, in due course, by `EXPRESSpass_2()`.

**Procedure:** WITHcreate  
**Parameters:** Expression expression - controlling expression for the with  
**Returns:** Statement body - controlled statement for the with  
**Description:** With\_Error\* errc - buffer for error code  
**Parameters:** With\_Statement statement - the with statement created  
**Returns:** Create a with statement.

**Procedure:** WITHget\_body  
**Parameters:** With\_Statement statement - statement to examine  
**Returns:** Statement - statement forming the body of the with statement

**Procedure:** WITHget\_control  
**Parameters:** With\_Statement statement - statement to examine  
**Returns:** Expression - the controlling expression  
**Description:** Retrieve the controlling expression from a with statement. This is the expression which will be prepended to any expression which cannot otherwise be evaluated in the current scope.

## 4.16 Symbol

**Type:** Symbol  
**Supertype:** -- none --

**Procedure:** SYMBOLget\_line\_number  
**Parameters:** Symbol symbol - symbol to examine  
**Returns:** int - line number of symbol

**Procedure:** SYMBOLget\_name  
**Parameters:** Symbol symbol - symbol to examine  
**Returns:** String - name of symbol

<b>Procedure:</b>	SYMBOLget_resolved
<b>Parameters:</b>	Symbol symbol - symbol to examine
<b>Returns:</b>	Boolean - is the symbol resolved?
<b>Description:</b>	Test whether a symbol has been resolved.
<b>Procedure:</b>	SYMBOLinitialize
<b>Parameters:</b>	-- none --
<b>Returns:</b>	void
<b>Description:</b>	Initialize the Symbol module. This is called by EXPRESSinitialize(), and so normally need not be called individually.
<b>Procedure:</b>	SYMBOLprint
<b>Parameters:</b>	Symbol
<b>Returns:</b>	void
<b>Description:</b>	Prints a Symbol. Exactly what is printed can be controlled by setting various elements of the variable symbol_print.
<b>Procedure:</b>	SYMBOLput_line_number
<b>Parameters:</b>	Symbol symbol - symbol to modify int number - line number for symbol
<b>Returns:</b>	void
<b>Description:</b>	Set a symbol's line number.
<b>Procedure:</b>	SYMBOLput_name
<b>Parameters:</b>	Symbol symbol - symbol to name String name - name of symbol
<b>Returns:</b>	void
<b>Description:</b>	Set the name of a symbol.
<b>Procedure:</b>	SYMBOLput_resolved
<b>Parameters:</b>	Symbol symbol - symbol to mark resolved
<b>Returns:</b>	void
<b>Description:</b>	Mark a symbol as being resolved. This is normally called by the client XXXput_resolved() functions, since a symbol cannot itself be resolved.

## 4.17 Type

<b>Private Type:</b>	Type
<b>Supertype:</b>	Symbol
<b>Type:</b>	Aggregate_Type
<b>Supertype:</b>	Type
<b>Type:</b>	Array_Type
<b>Supertype:</b>	Aggregate_Type
<b>Type:</b>	Bag_Type
<b>Supertype:</b>	Aggregate_Type
<b>Type:</b>	Binary_Type
<b>Supertype:</b>	Type

<b>Type:</b>	List_Type
<b>Supertype:</b>	Aggregate_Type
<b>Type:</b>	Set_Type
<b>Supertype:</b>	Aggregate_Type
<b>Private Type:</b>	Composed_Type
<b>Supertype:</b>	Type
<b>Type:</b>	Entity_Type
<b>Supertype:</b>	Composed_Type
<b>Type:</b>	Enumeration_Type
<b>Supertype:</b>	Composed_Type
<b>Type:</b>	Select_Type
<b>Supertype:</b>	Composed_Type
<b>Type:</b>	Generic_Type
<b>Supertype:</b>	Type
<b>Type:</b>	Logical_Type
<b>Supertype:</b>	Type
<b>Type:</b>	Boolean_Type
<b>Supertype:</b>	Logical_Type
<b>Type:</b>	Number_Type
<b>Supertype:</b>	Type
<b>Private Type:</b>	Sized_Type
<b>Supertype:</b>	Type
<b>Type:</b>	Integer_Type
<b>Supertype:</b>	Sized_Type
<b>Type:</b>	Real_Type
<b>Supertype:</b>	Sized_Type
<b>Type:</b>	String_Type
<b>Supertype:</b>	Sized_Type
<b>Type:</b>	Type_Reference
<b>Supertype:</b>	Type
<b>Constant:</b>	TYPEAGGREGATE
<b>Description:</b>	Type for general aggregate of generic.

<b>Constant:</b>	TYPE_BINARY
<b>Description:</b>	Binary type.
<b>Constant:</b>	TYPE_BOOLEAN
<b>Description:</b>	Boolean type.
<b>Constant:</b>	TYPE_GENERIC
<b>Description:</b>	The type 'generic.'
<b>Constant:</b>	TYPE_INTEGER
<b>Description:</b>	Integer type with default precision.
<b>Constant:</b>	TYPE_LOGICAL
<b>Description:</b>	Logical type.
<b>Constant:</b>	TYPE_META
<b>Description:</b>	Meta type (for TYPEOF expressions).
<b>Constant:</b>	TYPE_NUMBER
<b>Description:</b>	Number type.
<b>Constant:</b>	TYPE_REAL
<b>Description:</b>	Real type with default precision.
<b>Constant:</b>	TYPE_SET_OF_GENERIC
<b>Description:</b>	Type for unconstrained set of generic.
<b>Constant:</b>	TYPE_STRING
<b>Description:</b>	String type with default precision (length).
<b>Procedure:</b>	AGGR_TYPEget_optional
<b>Parameters:</b>	Aggregate_Type type - type to examine
<b>Returns:</b>	Boolean - are elements of this aggregate optional?
<b>Description:</b>	Retrieve the 'optional' flag from an aggregate type. This flag is true if and only if a legal instantiation of the type need not have all of its slots filled.
<b>Procedure:</b>	AGGR_TYPEget_unique
<b>Parameters:</b>	Aggregate_Type type - type to examine
<b>Returns:</b>	Boolean - must elements of this aggregate be unique?
<b>Description:</b>	Retrieve the 'unique' flag from an aggregate type. This flag is true if and only if a legal instantiation of the type may not contain duplicates.
<b>Procedure:</b>	AGGR_TYPEget_base_type
<b>Parameters:</b>	Aggregate_Type type - type to examine
<b>Returns:</b>	Type - the base type of the aggregate type
<b>Description:</b>	Retrieve the base type of an aggregate. This is the type of each element of an instantiation of the type.

<b>Procedure:</b>	AGGR_TYPEget_lower_limit
<b>Parameters:</b>	Aggregate_Type type - type to examine
<b>Returns:</b>	Expression - lower limit of the aggregate type
<b>Description:</b>	Retrieve an aggregate type's lower bound. For an array type, this is the lowest index; for other aggregate types, it specifies the minimum number of elements which the aggregate must contain.
<b>Procedure:</b>	AGGR_TYPEget_upper_limit
<b>Parameters:</b>	Aggregate_Type type - type to examine
<b>Returns:</b>	Expression - upper limit of the aggregate type
<b>Description:</b>	Retrieve an aggregate type's upper bound. For an array type, this is the high index; for other aggregate types, it specifies the maximum number of elements which the aggregate may contain.
<b>Procedure:</b>	AGGR_TYPEprint
<b>Parameters:</b>	Aggregate_Type
<b>Returns:</b>	void
<b>Description:</b>	Prints an Aggregate_Type. Exactly what is printed can be controlled by setting various elements of the variable aggr_type_print.
<b>Procedure:</b>	AGGR_TYPEput_optional
<b>Parameters:</b>	Aggregate_Type type - type to modify
<b>Returns:</b>	Boolean optional - are array elements optional?
<b>Description:</b>	void Set the 'optional' flag for an array type. This flag indicates that all slots in an instance of the type need not be filled.
<b>Procedure:</b>	AGGR_TYPEput_unique
<b>Parameters:</b>	Aggregate_Type type - type to modify
<b>Returns:</b>	Boolean unique - are aggregate elements required to be unique?
<b>Description:</b>	void Set the 'unique' flag for an aggregate type. This flag indicates that an instantiation of the type may not contain duplicate items.
<b>Procedure:</b>	AGGR_TYPEput_base_type
<b>Parameters:</b>	Aggregate_Type type - type to modify
<b>Returns:</b>	Type base - the base type for this aggregate
<b>Description:</b>	void Set the base type of an aggregate type. This is the type of every element.
<b>Procedure:</b>	AGGR_TYPEput_limits
<b>Parameters:</b>	Aggregate_Type type - type to modify
<b>Returns:</b>	Expression lower - lower bound for aggregate
<b>Description:</b>	Expression upper - upper bound for aggregate void Set the lower and upper bounds for an aggregate type. For an array type, these are the low and high indices; for other aggregates, these specify the minimum and maximum number of elements which an instance may contain.
<b>Procedure:</b>	COMP_TYPEadd_items
<b>Parameters:</b>	Composed_Type
<b>Returns:</b>	Linked_List
<b>Description:</b>	void Add to the list of items for a Composed_Type.

<b>Procedure:</b>	COMP_TYPEget_items
<b>Parameters:</b>	Composed_Type
<b>Returns:</b>	Linked_List of Symbol
<b>Description:</b>	Retrieve a composed types list of identifiers.
<b>Procedure:</b>	COMP_TYPEprint
<b>Parameters:</b>	Composed_Type
<b>Returns:</b>	void
<b>Description:</b>	Prints a Composed_Type. Exactly what is printed can be controlled by setting various elements of the variable comp_type_print.
<b>Procedure:</b>	COMP_TYPEput_items
<b>Parameters:</b>	Composed_Type
<b>Returns:</b>	Linked_List
<b>Description:</b>	void
<b>Description:</b>	Set the list of items for a Composed_Type.
<b>Procedure:</b>	ENT_TYPEget_entity
<b>Parameters:</b>	Entity_Type type - type to examine
<b>Returns:</b>	Entity - definition of entity type
<b>Description:</b>	Retrieve the (first) entity referenced by an entity type.
<b>Procedure:</b>	ENT_TYPEget_entity_list
<b>Parameters:</b>	Entity_Type type - type to examine
<b>Returns:</b>	Linked_List - definition of entity type
<b>Description:</b>	Retrieve a list of the entities referenced by an entity type.
<b>Procedure:</b>	ENT_TYPEput_entity
<b>Parameters:</b>	Entity_Type type - type to modify
<b>Returns:</b>	Entity entity - definition of type
<b>Description:</b>	void
<b>Description:</b>	Set the entity referred to by an entity type.
<b>Procedure:</b>	ENT_TYPEput_entity_list
<b>Parameters:</b>	Entity_Type type - type to modify
<b>Returns:</b>	Linked_List - definition of type
<b>Description:</b>	void
<b>Description:</b>	Set the list of entities referred to by an entity type.
<b>Procedure:</b>	ENUM_TYPEget_items
<b>Parameters:</b>	Enumeration_Type type - type to examine
<b>Returns:</b>	Linked_List - list of enumeration items
<b>Description:</b>	Retrieve an enumerated type's list of identifiers. Each element of this list is a Constant.
<b>Procedure:</b>	ENUM_TYPEput_items
<b>Parameters:</b>	Enumeration_Type type - type to modify
<b>Returns:</b>	Linked_List list - list of enumeration items
<b>Description:</b>	void
<b>Description:</b>	Set the list of identifiers for an enumerated type. Each element of this list should be a Constant.

<b>Procedure:</b>	SEL_TYPEget_items
<b>Parameters:</b>	Select_Type type - type to examine
<b>Returns:</b>	Linked_List - list of selectable types
<b>Description:</b>	Retrieve a list of the selectable types from a select type.
<b>Procedure:</b>	SEL_TYPEput_items
<b>Parameters:</b>	Select_Type type - type to modify
<b>Returns:</b>	Linked_List list - list of selectable types
<b>Description:</b>	void Set the list of selections for a select type. An instance of any these types is a legal instantiation of the select type. Each Type on the list should be of class TYPE_ENTITY or TYPE_SELECT.
<b>Procedure:</b>	SZD_TYPEget_precision
<b>Parameters:</b>	Sized_Type type - type to examine
<b>Returns:</b>	Expression - the precision specification of the type
<b>Description:</b>	Retrieve the precision specification from certain types. This specifies the maximum number of significant digits or characters in an instance of the type.
<b>Procedure:</b>	SZD_TYPEget_varying
<b>Parameters:</b>	Sized_Type type - type to examine
<b>Returns:</b>	Boolean - is the string type of varying length?
<b>Description:</b>	Retrieve the 'varying' flag from a string type. This flag is true if and only if the length of an instance may vary, up to the type's precision. It is true by default.
<b>Procedure:</b>	SZD_TYPEprint
<b>Parameters:</b>	Sized_Type
<b>Returns:</b>	void
<b>Description:</b>	Prints a Sized_Type. Exactly what is printed can be controlled by setting various elements of the variable szd_type_print.
<b>Procedure:</b>	SZD_TYPEput_precision
<b>Parameters:</b>	Sized_Type type - type to modify
<b>Returns:</b>	Expression prec - the precision of the type
<b>Description:</b>	void Set the precision of certain types. This is the maximum number of significant digits or characters in an instance.
<b>Procedure:</b>	SZD_TYPEput_varying
<b>Parameters:</b>	Sized_Type type - type to modify
<b>Returns:</b>	Boolean varying - is string type of varying length?
<b>Description:</b>	void Set the 'varying' flag of a string type. This flag indicates that the length of an instance may vary, up to the type's precision. The default behavior for a string type is to be varying, i.e., strings are initialized as if TYPEPut_varying(string, true) were called.
<b>Procedure:</b>	TYPEcompatible
<b>Parameters:</b>	Type lhs_type - type for left-hand-side of assignment
<b>Returns:</b>	Type rhs_type - type for right-hand-side of assignment
<b>Description:</b>	Boolean - are the types assignment compatible? Determine whether two types are assignment-compatible. It must be possible to assign a value of rhs_type into a slot of lhs_type.

<b>Procedure:</b>	TYPEget_name
<b>Parameters:</b>	Type type - type to examine
<b>Returns:</b>	String - the name of the type
<b>Description:</b>	Return the name of the type.
<b>Procedure:</b>	TYPEget_original_type
<b>Parameters:</b>	Type type
<b>Returns:</b>	Type
<b>Description:</b>	returns the original type, allowing a way to see through TYPE declarations.
<b>Procedure:</b>	TYPEget_size
<b>Parameters:</b>	Type type - type to examine
<b>Returns:</b>	int - logical size of a type instance
<b>Description:</b>	Compute the size of an instance of some type. Simple types all have size 1, as does a select type. The size of an aggregate type is the maximum number of elements an instance can contain; and the size of an entity type is its total attribute count. If an aggregate type is unbounded, the constant TYPE_UNBOUNDED_SIZE is returned. This value may be ambiguous; the upper bound of the type should be relied on to determined unboundedness. It is intended that the initial memory allocation for such an aggregate should give space for TYPE_UNBOUNDED_SIZE elements, and that this should grow as needed. By returning some reasonable initial size, this call allows its return value to be used immediately as a parameter to a memory allocator, without being checked for validity. This is the approach taken in the STEP Working Form [Clark90d], [Clark90e].
<b>Procedure:</b>	TYPEget_where_clause
<b>Parameters:</b>	Type type - type to examine
<b>Returns:</b>	Linked_List - the type's WHERE clause
<b>Description:</b>	Retrieve the WHERE clause associated with a type. Each element of the returned list will be an Expression which computes a Logical result.
<b>Procedure:</b>	TYPEinitialize
<b>Parameters:</b>	-- none --
<b>Returns:</b>	void
<b>Description:</b>	Initialize the Type module. This is called by EXPRESSinitialize(), and so normally need not be called individually.
<b>Procedure:</b>	TYPEprint
<b>Parameters:</b>	Type
<b>Returns:</b>	void
<b>Description:</b>	Prints a Type. Exactly what is printed can be controlled by setting various elements of the variable type_print.
<b>Procedure:</b>	TYPEput_name
<b>Parameters:</b>	Type type - type to modify
<b>Returns:</b>	String name - new name for type
<b>Description:</b>	Set the name of a type.

<b>Procedure:</b>	TYPEput_original_type
<b>Parameters:</b>	TYPE new_type TYPE original_type
<b>Returns:</b>	void
<b>Description:</b>	Sets original type. See TYPEget_original_type.
<b>Procedure:</b>	TYPEput_where_clause
<b>Parameters:</b>	Type type - type to modify Linked_List - the type's WHERE clause
<b>Returns:</b>	void
<b>Description:</b>	Set the WHERE clause associated with a type. Each element of the list should be an Expression which computes a Logical result.
<b>Procedure:</b>	TYPEResolve
<b>Parameters:</b>	Type type - type to resolve Scope scope - scope in which to resolve
<b>Returns:</b>	void
<b>Description:</b>	Resolve all references in a type definition, and transform a type reference into the appropriate Type or Entity construct. This is called, in due course, by EXPRESSpass_2().
<b>Procedure:</b>	TYPE_REFget_full_name
<b>Parameters:</b>	Type_Reference type - type reference to examine
<b>Returns:</b>	Expression - [qualified] identifier expression for type reference
<b>Description:</b>	Retrieve the identifier expression for a type reference. This expression consists of identifier components assembled into binary expressions with OP_DOT.
<b>Procedure:</b>	TYPE_REFprint
<b>Parameters:</b>	Type_Reference
<b>Returns:</b>	void
<b>Description:</b>	Prints a Type_Reference. Exactly what is printed can be controlled by setting various elements of the variable type_ref_print.
<b>Procedure:</b>	TYPE_REFput_full_name
<b>Parameters:</b>	Type_Reference type - type reference to modify
<b>Returns:</b>	Expression name - [qualified] identifier expression for type reference
<b>Description:</b>	void Set the identifier expression for a type reference.

## 4.18 Use

<b>Procedure:</b>	USEresolve
<b>Parameters:</b>	Scope
<b>Returns:</b>	void
<b>Description:</b>	resolves all references (from USE statements) in a scope.

## 4.19 Variable

<b>Type:</b>	Variable
<b>Supertype:</b>	Symbol

<b>Procedure:</b>	VARcreate
<b>Parameters:</b>	<p>String name - name of variable to create</p> <p>Type type - type of variable to create</p> <p>Error* errc - buffer for error code</p>
<b>Returns:</b>	Variable - the Variable created
<b>Description:</b>	Create a new variable. The reference class of the variable is, by default, REF_DYNAMIC. All special flags associated with the variable (e.g., optional) are initially false.
<b>Procedure:</b>	VARget_derived
<b>Parameters:</b>	Variable var - variable to examine
<b>Returns:</b>	Boolean - value of variable's derived flag
<b>Description:</b>	Retrieve the value of a variable's 'derived' flag. This flag indicates that an entity attribute's value should always be computed by its initializer; no value will ever be specified for it.
<b>Procedure:</b>	VARget_initializer
<b>Parameters:</b>	Variable var - variable to modify
<b>Returns:</b>	Expression - variable initializer
<b>Description:</b>	Retrieve the expression used to initialize a variable.
<b>Procedure:</b>	VARget_inverse
<b>Parameters:</b>	Variable
<b>Returns:</b>	Symbol
<b>Description:</b>	Returns inverse relationship of a variable. Typically used after resolution, this will be either a Set_Type or an Identifier of the entity of the variable.
<b>Procedure:</b>	VARget_name
<b>Parameters:</b>	Variable var - variable to examine
<b>Returns:</b>	String - the name of the variable
<b>Procedure:</b>	VARget_offset
<b>Parameters:</b>	Variable var - variable to examine
<b>Returns:</b>	int - offset to variable in local frame
<b>Description:</b>	Retrieve the offset to a variable in its local frame. This offset alone is not sufficient in the case of an entity attribute (see ENTITYget_attribute_offset()).
<b>Procedure:</b>	VARget_optional
<b>Parameters:</b>	Variable var - variable to examine
<b>Returns:</b>	Boolean - value of variable's optional flag
<b>Description:</b>	Retrieve the value of a variable's 'optional' flag. This flag indicates that a particular entity attribute need not have a value when the entity is instantiated.
<b>Procedure:</b>	VARget_type
<b>Parameters:</b>	Variable var - variable to examine
<b>Returns:</b>	Type - the type of the variable
<b>Procedure:</b>	VARget_variable
<b>Parameters:</b>	Variable var - variable to examine
<b>Returns:</b>	Boolean - value of variable's variable flag
<b>Description:</b>	Retrieve the value of a variable's 'variable' flag. This flag indicates that an algorithm parameter is to be passed by reference, so that it can be modified by the callee.

<b>Procedure:</b>	.VARinitialize
<b>Parameters:</b>	-- none --
<b>Returns:</b>	void
<b>Description:</b>	Initialize the Variable module. This is called by EXPRESSinitialize(), and so normally need not be called individually.
<b>Procedure:</b>	VARprint
<b>Parameters:</b>	Variable
<b>Returns:</b>	void
<b>Description:</b>	Prints a Variable. Exactly what is printed can be controlled by setting various elements of the variable var_print.
<b>Procedure:</b>	VARput_derived
<b>Parameters:</b>	Variable var - variable to modify
<b>Returns:</b>	Boolean val - new value for derived flag void
<b>Description:</b>	Set the value of the 'derived' flag for a variable. This flag is currently redundant, as a derived attribute can be identified by the fact that it has an initializing expression. This may not always be true, however.
<b>Procedure:</b>	VARput_initializer
<b>Parameters:</b>	Variable var - variable to modify
<b>Returns:</b>	Expression init - initializer void
<b>Description:</b>	Set the initializing expression for a variable.
<b>Procedure:</b>	VARput_inverse
<b>Parameters:</b>	Variable
<b>Returns:</b>	Symbol void
<b>Description:</b>	Set inverse relationship for a variable. See VARget_inverse.
<b>Procedure:</b>	VARput_offset
<b>Parameters:</b>	Variable var - variable to modify
<b>Returns:</b>	int offset - offset to variable in local frame void
<b>Description:</b>	Set a variable's offset in its local frame. Note that in the case of an entity attribute, this offset is <i>from the first locally defined attribute</i> , and must be used in conjunction with entity's initial offset (see ENTITYget_attribute_offset()).
<b>Procedure:</b>	VARput_optional
<b>Parameters:</b>	Variable var - variable to modify
<b>Returns:</b>	Boolean val - value for optional flag void
<b>Description:</b>	Set the value of the 'optional' flag for a variable. This flag indicates that a particular entity attribute need not have a value when the entity is instantiated. It is initially false.
<b>Procedure:</b>	VARput_type
<b>Parameters:</b>	Variable
<b>Returns:</b>	Type void
<b>Description:</b>	Set the type of a variable.

<b>Procedure:</b>	VARput_variable
<b>Parameters:</b>	Variable var - variable to modify Boolean val - new value for variable flag
<b>Returns:</b>	void
<b>Description:</b>	Set the value of the 'variable' flag for a variable. This flag indicates that an algorithm parameter is to be passed by reference, so that it can be modified by the callee.
<b>Procedure:</b>	VARresolve
<b>Parameters:</b>	Variable variable - variable to resolve Scope scope - scope in which to resolve
<b>Returns:</b>	void
<b>Description:</b>	Resolve all symbol references in a variable definition. This is called, in due course, by EXPRESSpass_2( ).

## 5 Express Working Form Error Codes

The Error module, which is used to manipulate these error codes, is described in [Clark90c].

<b>Error:</b>	ERROR_bail_out
<b>Defined In:</b>	Express
<b>Severity:</b>	SEVERITY_DUMP
<b>Meaning:</b>	Fed-X internal error
<b>Format:</b>	-- none --
<b>Error:</b>	ERROR_control_boolean_expected
<b>Defined In:</b>	Loop_Control
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	The controlling expression for a while or until does not seem to return boolean. In the current implementation, this message can be erroneously produced because proper types are not derived for complex expressions; thus, an expression which truly does compute a boolean result may not appear to do so according to the Working Form.
<b>Format:</b>	-- none --
<b>Error:</b>	ERROR_corrupted_expression
<b>Defined In:</b>	Expression
<b>Severity:</b>	SEVERITY_DUMP
<b>Meaning:</b>	Fed-X internal error: an Expression structure was corrupted
<b>Format:</b>	%s - function detecting error
<b>Error:</b>	ERROR_corrupted_statement
<b>Defined In:</b>	Statement
<b>Severity:</b>	SEVERITY_DUMP
<b>Meaning:</b>	Fed-X internal error: a Statement structure was corrupted
<b>Format:</b>	%s - function detecting error

<b>Error:</b>	ERROR_corrupted_type
<b>Defined In:</b>	Type
<b>Severity:</b>	SEVERITY_DUMP
<b>Meaning:</b>	Fed-X internal error: a Type structure was corrupted
<b>Format:</b>	%s - function detecting error
<b>Error:</b>	ERROR_duplicate_declaration
<b>Defined In:</b>	Scope
<b>Severity:</b>	SEVERITY_ERROR
<b>Meaning:</b>	A symbol was redeclared in the same scope
<b>Format:</b>	%s - name of redeclared symbol %d - line number of previous declaration
<b>Error:</b>	ERROR_inappropriate_use
<b>Defined In:</b>	Scope
<b>Severity:</b>	SEVERITY_ERROR
<b>Meaning:</b>	A symbol was used in a context which is inappropriate for its declaration.
<b>Format:</b>	%s - the name of the symbol
<b>Error:</b>	ERROR_include_file
<b>Defined In:</b>	Scanner
<b>Severity:</b>	SEVERITY_ERROR
<b>Meaning:</b>	An INCLUDEd file could not be opened.
<b>Format:</b>	%s - the name of the file
<b>Error:</b>	ERROR_integer_expression_expected
<b>Defined In:</b>	Expression
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	A non-integer expression was encountered in an integer-only context
<b>Format:</b>	-- none --
<b>Error:</b>	ERROR_integer_literal_expected
<b>Defined In:</b>	Expression
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	A non-integer or non-literal was encountered in an integer-literal context
<b>Format:</b>	-- none --
<b>Error:</b>	ERROR_logical_literal_expected
<b>Defined In:</b>	Expression
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	A non-logical or non-literal was encountered in a logical-literal context
<b>Format:</b>	-- none --
<b>Error:</b>	ERROR_missing_subtype
<b>Defined In:</b>	Pass2
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	An entity which lists a particular supertype does not appear in that entity's subtype list.
<b>Format:</b>	%s - the name of the subtype %s - the name of the supertype

<b>Error:</b>	ERROR_missing_supertype
<b>Defined In:</b>	Pass2
<b>Severity:</b>	SEVERITY_ERROR
<b>Meaning:</b>	An entity which lists a particular subtype does not appear in that entity's supertype list.
<b>Format:</b>	%s - the name of the supertype %s - the name of the subtype
 <b>Error:</b>	 ERROR_nested_comment
<b>Defined In:</b>	Scanner
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	A start comment symbol (* was encountered within a comment.
<b>Format:</b>	-- none --
 <b>Error:</b>	 ERROR_overloaded_attribute
<b>Defined In:</b>	Pass2
<b>Severity:</b>	SEVERITY_ERROR
<b>Meaning:</b>	An attribute name was previously declared in a supertype
<b>Format:</b>	%s - the attribute name %s - the name of the supertype with the previous declaration
 <b>Error:</b>	 ERROR_real_literal_expected
<b>Defined In:</b>	Expression
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	A non-real or non-literal was encountered in a real-literal context
<b>Format:</b>	-- none --
 <b>Error:</b>	 ERROR_set_literal_expected
<b>Defined In:</b>	Expression
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	A non-set or non-literal was encountered in a set-literal context
<b>Format:</b>	-- none --
 <b>Error:</b>	 ERROR_set_scan_set_expected
<b>Defined In:</b>	Loop_Control
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	The control set for a set scan control is not a set
<b>Format:</b>	-- none --
 <b>Error:</b>	 ERROR_shadowed_declaration
<b>Defined In:</b>	Pass2
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	A symbol declaration shadows a definition in an outer (or assumed) scope.
<b>Format:</b>	%s - name of redeclared symbol %d - line number of previous declaration
 <b>Error:</b>	 ERROR_string_literal_expected
<b>Defined In:</b>	Expression
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	A non-string or non-literal was encountered in a string-literal context
<b>Format:</b>	-- none --

<b>Error:</b>	ERROR_syntax
<b>Defined In:</b>	Express
<b>Severity:</b>	SEVERITY_EXIT
<b>Meaning:</b>	Unrecoverable syntax error
<b>Format:</b>	%s - description of error %s - name of scope in which error occurred
 <b>Error</b>	 ERROR_undefined_identifier
<b>Defined In:</b>	Pass2
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	An identifier was referenced which has not been declared. This error only produces a warning because Fed-X does not deal with all of the scoping issues in algorithms.
<b>Format:</b>	%s - the name of the identifier
 <b>Error:</b>	 ERROR_undefined_type
<b>Defined In:</b>	Pass2
<b>Severity:</b>	SEVERITY_ERROR
<b>Meaning:</b>	An undeclared identifier was used in a context which requires a type.
<b>Format:</b>	%s - the name of the type
 <b>Error:</b>	 ERROR_unknown_expression_class
<b>Defined In:</b>	Expression
<b>Severity:</b>	SEVERITY_DUMP
<b>Meaning:</b>	Fed-X internal error
<b>Format:</b>	%d - the offending expression class %s - the context (function) in which the error occurred
 <b>Error:</b>	 ERROR_unknown_schema
<b>Defined In:</b>	Pass2
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	An unknown schema was ASSUMEd
<b>Format:</b>	%s - the assumed schema name
 <b>Error:</b>	 ERROR_unknown_subtype
<b>Defined In:</b>	Pass2
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	An entity lists a subtype which is not itself declared as an entity.
<b>Format:</b>	%s - the subtype name %s - the supertype name
 <b>Error:</b>	 ERROR_unknown_supertype
<b>Defined In:</b>	Pass2
<b>Severity:</b>	SEVERITY_EXIT
<b>Meaning:</b>	An entity lists a supertype which is not itself declared as an entity. Fed-X is unable to proceed in this situation.
<b>Format:</b>	%s - the supertype name %s - the subtype name

<b>Error:</b>	ERROR_unknown_type_class
<b>Defined In:</b>	Type
<b>Severity:</b>	SEVERITY_DUMP
<b>Meaning:</b>	Fed-X internal error
<b>Format:</b>	%d - the offending type class %s - the context (function) in which the error occurred
<b>Error:</b>	ERROR_wrong_operand_count
<b>Defined In:</b>	Expression
<b>Severity:</b>	SEVERITY_WARNING
<b>Meaning:</b>	Mismatch between actual and expected (on the basis of code context) operand count
<b>Format:</b>	%s - the operator

## 6

## Building Fed-X

The Fed-X toolkit is distributed in two ways. The usual form is the latest release of the software. An alternate form is the RCS archives [Bodarky91] which contain all prior releases.

If you only have the latest release of the software, simply visit each directory named src and type 'make install'. This will create the necessary libraries. You may skip the rest of this section.

The following discussion assumes you have the RCS archives. To build the toolkit, you must find out where the archives are and where you would like to build the toolkit. This discussion assumes that the toolkit archives are stored in ~pdes and you would like to build it in ~/pdes.

First create the directory in which you are going to keep all your files.

```
mkdir ~/pdes
```

Check out a copy of make\_rules.

```
cd ~/pdes
mkdir include
cd include
co ~pdes/include/make_rules
```

make\_rules contains definitions common to all other parts of Fed-X as well as applications. If you examine it, you will find ways to customize the toolkit. For example, you can choose whether to use yacc or bison by changing this file. Only one change will be described in detail here. Namely, you must tell make\_rules the directory in which you are keeping all your Fed-X code.

In order to make this change, start by making it writeable:

```
chmod +w make_rules
```

Change the definition of PDES to reflect the root of the directories where you have your Fed-X code stored. Note that Make does not understand the ~ notation – thus, you must provide the hardcoded path, which for this example is assumed to be /home/fred:

```
PDES=/home/fred/pdes
```

Fed-X will ultimately be stored in several libraries. A directory must be created to contain the libraries. It is created as follows:

```
mkdir -p ~/pdes/arch/lib
```

If you are using bison, you should now create or link the bison library to this directory. For example, to create the library from scratch:

```
cd ~/pdes/src/libbison
co CheckOut
CheckOut
make install
```

In order to build the libraries, several programs must exist. These live in ~pdes/bin and it is normally sufficient to create a symbolic link between this and your own bin directory as:

```
ln -s ~pdes/bin ~/pdes/bin
```

If you already have a directory by that name, you may link the individual files:

```
ln -s ~pdes/bin/* ~/pdes/bin
```

Fed-X is composed of sources in two directories and include files in two other directories. The following example extracts the files from all four directories. After running each CheckOut, expect a page or so of output as each file composing the toolkit is checked out. The command make install compiles the toolkit and installs the library version in the arch/lib directory created previously.

```
cd ~/pdes/include/libmisc
co CheckOut
CheckOut
cd ~/pdes/src/libmisc
co CheckOut
CheckOut
make install
cd ~/pdes/include/express
co CheckOut
CheckOut
cd ~/pdes/src/express
co CheckOut
CheckOut
```

```
make .install
```

You can now build applications with Fed-X

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## Building Applications with Fed-X

Assuming the Fed-X toolkit has been built (as described in the previous section), building an application requires compiling and linking with the toolkit.

The easiest way to do this is copy the `Makefile` and `main.c` from an extant Fed-X application and modify it as necessary. For example, `fedex` is a very simple program that calls the toolkit to create a working form and do nothing else. To get `fedex`, create a directory for it and check out the code:

```
mkdir ~/pdes/src/fedex
cd ~/pdes/src/fedex
co CheckOut
CheckOut
```

If you want to compile `fedex` itself, run make::

```
cd ~/pdes/src/fedex
make
```

Now you may copy the `Makefile` and `main.c` as appropriate for your application.

## A

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## BIBLIOGRAPHIC DATA SHEET

1. PUBLICATION OR REPORT NUMBER NISTIR 4814
2. PERFORMING ORGANIZATION REPORT NUMBER
3. PUBLICATION DATE APRIL 1992

## 4. TITLE AND SUBTITLE

The NIST Express Working Form Programmer's Reference

## 5. AUTHOR(S)

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## 6. PERFORMING ORGANIZATION (IF JOINT OR OTHER THAN NIST, SEE INSTRUCTIONS)

U.S. DEPARTMENT OF COMMERCE  
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY  
GAITHERSBURG, MD 20899

## 7. CONTRACT/GANT NUMBER

## 8. TYPE OF REPORT AND PERIOD COVERED

## 9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (STREET, CITY, STATE, ZIP)

Office of the Secretary of Defense  
CALS Program Office  
Pentagon  
Washington, DC 20301-8000

## 10. SUPPLEMENTARY NOTES

## 11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

The Product Data Exchange using STEP (PDES) is an emerging standard for the exchange of product information among various manufacturing applications. PDES includes an information model written in the Express language; other PDES-related information models are also written in Express. The National PDES Testbed at NIST has developed software to manipulate and translate Express models. This software consists of an in-memory working form and an associated Express language parser, Fed-X. The internal operation of the Fed-X parser is described. The implementation of the data abstractions which make up the Express Working Form is discussed, and specifications are given for the Working Form access functions. The creation of Express language translators using Fed-X is discussed.

This document has been revised to reflect modifications in the implementation of Fed-X software to support changes in the Express language.

## 12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

data modeling; Express; PDES; Product Data Exchange using STEP; schema translation; Standard for the Exchange of Product Model Data; STEP

## 13. AVAILABILITY

X	UNLIMITED
	FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NATIONAL TECHNICAL INFORMATION SERVICE (NTIS).
	ORDER FROM SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, DC 20402.
X	ORDER FROM NATIONAL TECHNICAL INFORMATION SERVICE (NTIS), SPRINGFIELD, VA 22161.

## 14. NUMBER OF PRINTED PAGES

62

## 15. PRICE

A04





